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August 1994

US Army Corps
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Waterways Experiment
Station

Ship Navigation Simulation Study, Pascagoula Harbor Improvement Project, Pascagoula, Mississippi

by J. Christopher Hewlett

WES

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Prepared for U.S. Army Engineer District, Mobile

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Final report

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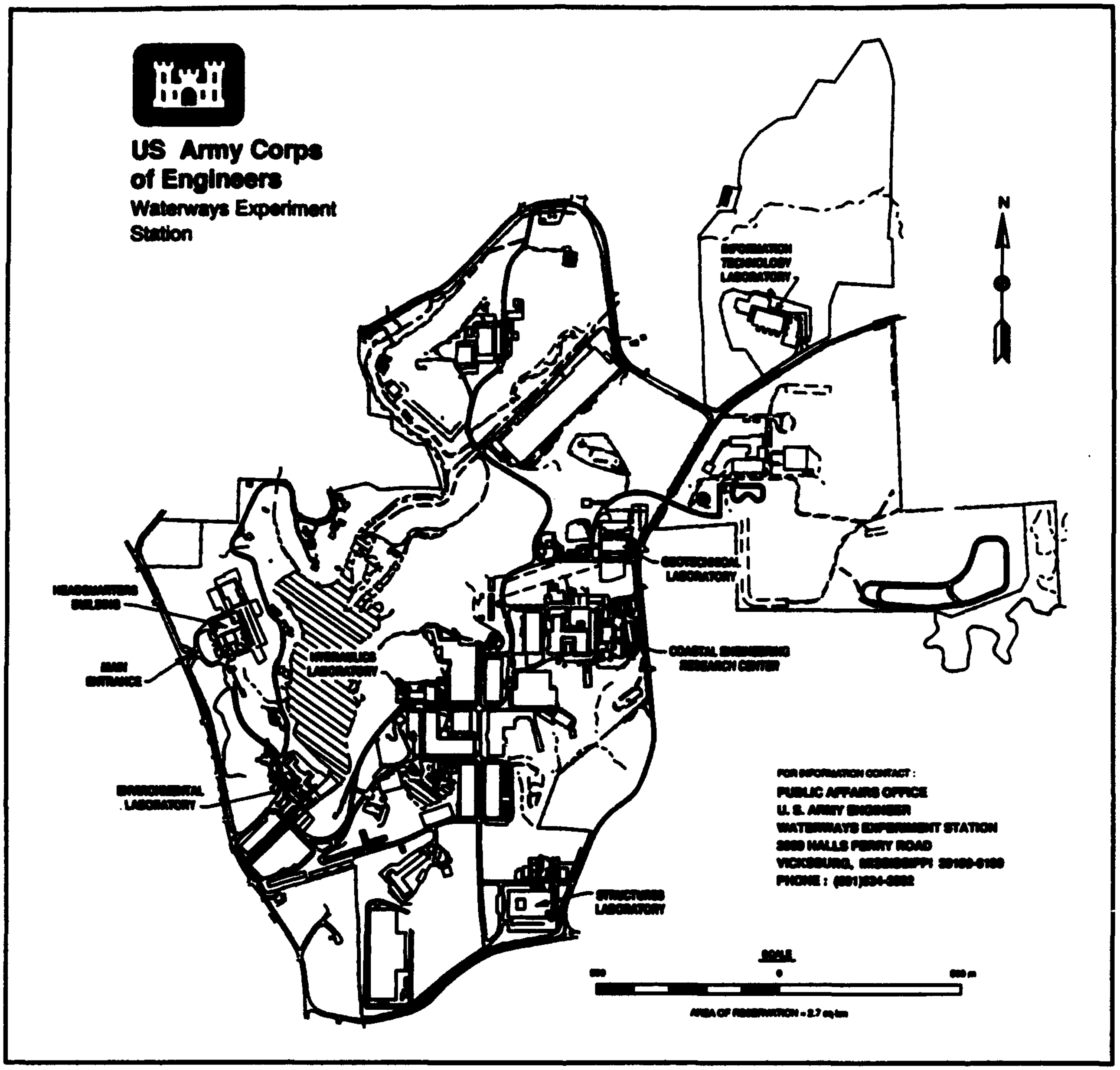

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Preface

This investigation was performed by the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) for the U. S. Army Engineer District, Mobile (SAM). The study was conducted with the WES research ship simulator during the period May 1988 - May 1994.

The investigation was conducted by Mr. J. Christopher Hewlett of the Navigation Branch, Waterways Division, Hydraulics Laboratory, WES, under the general supervision of Messrs. Frank A. Herrmann, Jr., Director of the Hydraulics Laboratory; Richard A. Sager, Assistant Director of the Hydraulics Laboratory; and M. B. Boyd, Chief of the Waterways Division; and Dr. Larry L. Daggett, Chief of the Navigation Branch. This report was prepared by Mr. Hewlett.

Acknowledgement goes to the Pascagoula Bar Pilots Association for providing professional pilots for the study. Also, thanks go to Mr. Pete Robinson, the engineer in charge of the project at Mobile District.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
knots (international)	0.5144444	meters per second
miles (U.S. nautical)	1.852	kilometers
miles (U.S. statute)	1.609347	kilometers
tons (2,000 pounds, mass)	907.1847	kilograms

1 Introduction

Pascagoula Harbor

Physical description

Pascagoula Harbor is located on the Gulf of Mexico coast in the state of Mississippi approximately 30 miles[1] west of Mobile Bay, Alabama. The harbor, shown on Figure 1, consists of two separate channel legs: the Pascagoula Channel and the Bayou Casotte Channel. These two channels are both served by the Entrance Channel, the Horn Island Pass and the lower reach of the Pascagoula Channel. Near the center of the Mississippi Sound the channel splits into the Bayou Casotte Channel heading approximately due north and the Pascagoula Channel heading northwest toward the mouth of the Pascagoula River (known locally as Singing River). Major industrial activity in the Bayou Casotte Harbor includes a large petroleum refinery, owned and operated by Chevron USA, Inc., a coal-coke dock and other bulk commodity loading facilities including one used by LASH (lighter aboard ship) ships. Primary commercial activity in the Pascagoula Harbor includes the Ingalls Shipbuilding, Inc. shipyard, a public grain terminal and numerous general cargo loading facilities. Construction and repair of jack-up and semi-submersible oil drilling rigs are conducted in both Bayou Casotte and Pascagoula Harbors.

The main physical features of the present channels are

a. The Entrance Channel (also known as the Horn Island Pass Channel) which is approximately 4 nautical miles long. This channel leads into the Mississippi Sound from the southwest and turns and enters the sound through the Horn Island Pass. The present width of the channel is 350 ft with a project depth of 40 ft below Gulf Coast low water datum (gclwd). The width of the two bends in the Horn Island Pass is approximately 450 ft.

b. The Lower Pascagoula Channel (also known as the Main Channel) which is approximately 4 nautical miles long. This channel crosses

[1] A table of factors for converting non-SI units of measurement to SI units is presented on page viii.

about one-half of the Mississippi Sound in an approximate north-south direction terminating at the intersection of the Bayou Casotte and Pascagoula Channels. The present width of the channel is 350 ft with a depth of 38 ft gclwd.

c. The Upper Pascagoula Channel (also known as the Main Channel) which is approximately 6 nautical miles long. The channel crosses the Mississippi Sound in a northwesterly direction before turning to a northerly direction at the mouth of the Pascagoula River. The deep-draft channel ends at the turning basin south of the Louisville and Nashville (L & N) Railroad bridge in the city of Pascagoula. The present width of the channel is 350 ft with a depth of 38 ft gclwd.

d. The Bayou Casotte Channel which is approximately 4 nautical miles long. The channel diverges from the main channel at the shoreward end of the Lower Pascagoula Channel and lies in an almost due north-south direction. Near the mouth of the Bayou Casotte inner harbor the channel makes a slight bend toward the east, enters the harbor area and terminates at a turning basin. The channel is presently 225 ft wide through most of its length widening to 300 ft in the inner part of the harbor. The existing project depth is 38 ft gclwd.

Presently, the types of ships calling at the Port of Pascagoula include LASH ships, bulk carriers and oil tankers. The LASH ships are the longest with lengths overall (LOA) up to 894 ft with beams of 100 ft. The oil tankers are up to 784 ft LOA with beams of 122 ft and the largest bulk carriers are Panamax class vessels up to 750 ft LOA and 106 ft wide. Primarily, only the bulk carriers go into the Pascagoula side of the port and all three types of ships use the Bayou Casotte channel, although the bulk carriers in Bayou Casotte are somewhat smaller, ranging up to 650 ft in length. The drafts of visiting vessels run up to 36 ft except for the LASH ships which usually do not draft deeper than 34 ft. The fleet of oil tankers in the area operates in a lightering capability which requires frequent loading/unloading trips between large tankers moored offshore and the refinery in Bayou Casotte Harbor. This tanker fleet includes a new class of lightering tankers which are equipped with the recently developed Schilling rudder, which at low ship speeds operates similar to a stern thruster. These tankers were recently introduced in Pascagoula in hopes of utilizing their maneuverability for easier operation, especially for nighttime transits, which at the present time are not allowed by the pilots. Further discussion concerning the impact of these tankers on the simulation study will be presented later.

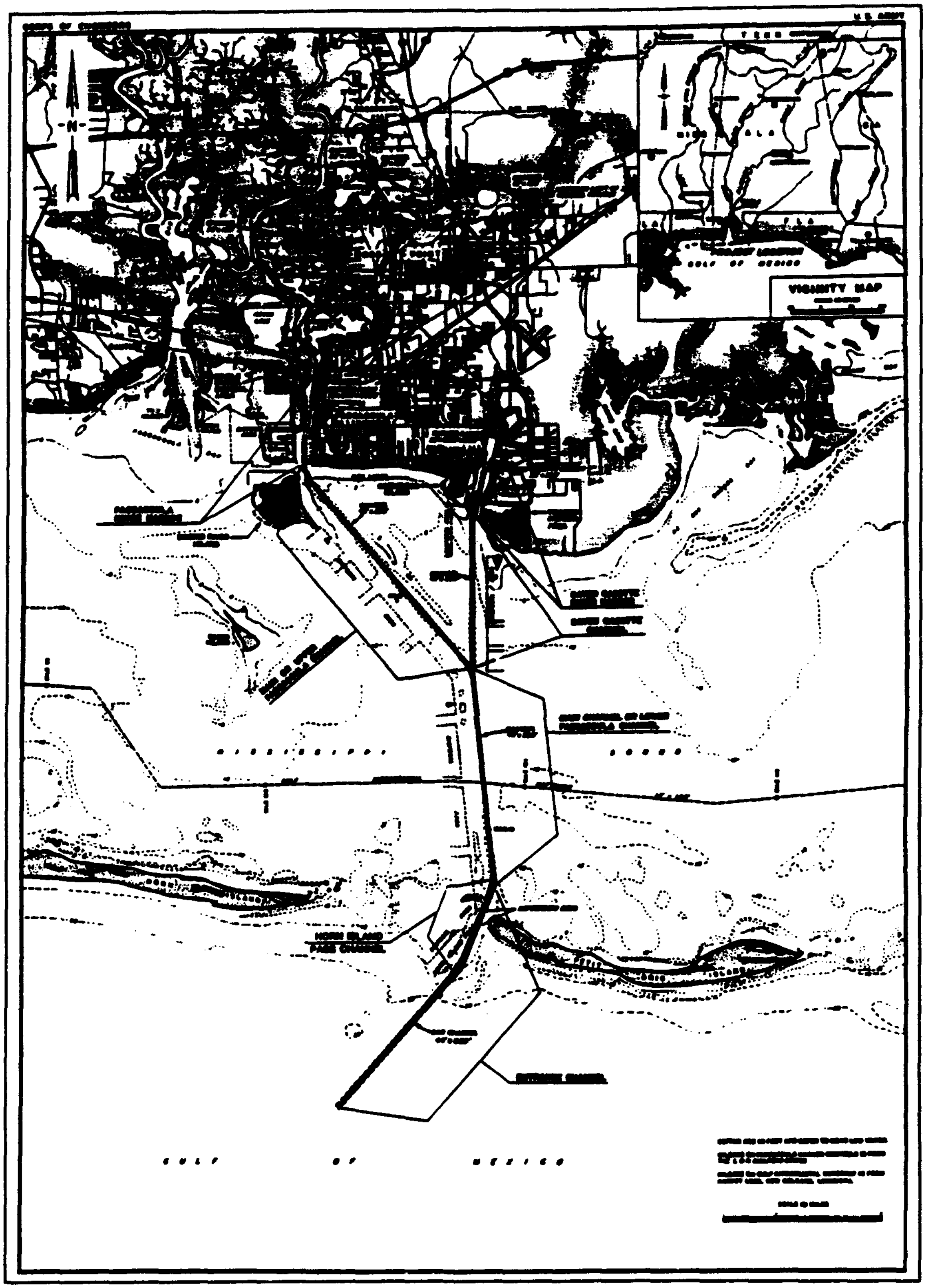

Figure 1. Study area

Currently, the predominant business in the Pascagoula River is that of grain export which means that the ships are in ballast or light load when they enter Pascagoula and leave heavily laden. The ships are usually turned in the turning basin near the railroad bridge at first arrival. The Bayou Casotte channel serves mainly the import business; consequently, the bulk carriers and tankers usually come in heavily laden, tie up, unload and then are turned in the turning basin at the head of the channel when in light load condition. This means that the tankers, whose destination is near the mouth of Bayou Casotte, must transit the entire length of the inner harbor before reaching the turning basin. The bulk carriers usually are tied up at commercial facilities closer to the existing turning basin and, therefore, do not take as long to be turned around. The nature of the LASH barge business is such that generally the LASH ships pick up about the same amount of cargo as is unloaded; therefore, these ships arrive and depart with roughly the same draft. The LASH vessels have only one destination in the Bayou Casotte harbor. The usual practice is for the LASH ships to be taken beyond the berth and, with tug-assist, backed in port-side-to. At departure these ships pull directly out into the channel and proceed south.

Navigation problems

Navigation difficulties in the study area are a result of the combination of narrow channels, long ships and cross winds and currents. Also, the length of the channel reaches cause course keeping difficulties as the pilots fight strong sway and yaw forces. At times the pilots have to maintain a high rate of speed, especially in the Entrance and Horn Island Pass Channels, to counteract the set caused by these forces. These high rates of speed cause the ships to react (at times rather extremely) to the submerged banks adjacent to the channels through the processes of bank suction and shear. These bank effects sometimes cause the ships to shear back and forth across the channel while the pilot tries to reduce speed and control the ship with rudder movement. This phenomenon is especially severe when the pilot is in the process of slowing his vessel in preparation for the bends or when nearing the harbor. Furthermore, in Horn Island Pass, strong northerly or northwesterly winds can constitute an additional driving force for the ebbing tide and, at such times, the currents can cause difficulty for loaded ships. In the Lower Pascagoula Channel, the primary difficulty occurs when a LASH ship transits the reach during times of easterly or westerly winds. These directions are perpendicular to the channel in this reach and, after the wind has blown steadily for a significant period of time, cross currents develop in the channel. These cross currents, together with the wind itself, can make course keeping difficult while piloting a ship with high windage area such as a LASH ship. Another area that creates problems at certain times is the bend at the Pascagoula River entrance in the Upper Pascagoula Channel. During times of high fresh water outflow from the river, difficulties can occur during negotiation of the bend. Also, the intersection between the Pascagoula and Bayou Casotte Channels is difficult to maneuver, depending on which direction and which channel the ship is

entering and leaving. In the Bayou Casotte Channel even though there is little current and tugs are usually available for slowing the vessel, the narrowness of the channel can cause navigation difficulties because of bank suction and wind.

Along with the navigation problems discussed above, additional difficulties are experienced during nighttime transits, according to the Pascagoula pilots. The specific area of concern is the Entrance Channel and Horn Island Pass which the pilots report as being very demanding at nighttime because of the 350-ft channel width and the effect of limited visibility. Because of these concerns the pilots have imposed time-of-day restrictions on certain ships; most notably, LASH ships and some tankers. The introduction of the new design lightering tankers has exacerbated this problem because the pilots have experienced less maneuverability with these ships than expected. The pilots' concerns about nighttime transits were the basis of the district's request for an extension of the simulator study. This extension consisted of additional simulations which were setup to test nighttime conditions in only the Entrance Channel and Horn Island Pass and were organized after completion of the initial daytime simulations conducted in all the channel segments.

Proposed channel improvements

A proposed plan for channel modifications in the Pascagoula Harbor has been made by US Army Engineer District (USAED) Mobile, Alabama. The proposal includes a 4-ft deepening to 44 ft in the Entrance Channel and 42 ft in the remaining channel reaches from the existing 40 ft and 38 ft, respectively. As originally proposed in the district's Feasibility Report, the following modifications to channel alignment and width were recommended:

a. The Entrance Channel would be widened from the existing 350 ft to 550 ft with the same alignment.

b. The channel through Horn Island Pass would be moved approximately 500 ft to the west of its present location in order to compensate for the natural drift of the position of the deepest part of the inlet channel. The width of this part of the channel would be 600 ft with appropriate extra widenings at the two bends. The existing sediment impounding basin adjacent to Petit Bois Island would be moved with the channel to the west and lengthened.

c. The Pascagoula Channel from the connection with the Horn Island Pass Channel all the way to the Pascagoula River harbor would remain 350 ft wide. Bend wideners would be constructed at the intersection with Bayou Casotte Channel and at the mouth of the Pascagoula River.

d. The Bayou Casotte Channel would be widened from the existing 225 ft to a width of 350 ft. A bend widener would be provided at the

intersection with the Pascagoula Channel and at the mouth of the Bayou Casotte.

e. A new turning basin would be provided at the entrance to the Bayou Casotte inner harbor on the west side opposite the oil refinery. A turning diameter of 1150 ft would exist in the proposed basin with a length along the back edge of 600 ft.

Simulation study proposed conditions

After completion of the Feasibility Report subsequent heightened concern over project costs lead the District to consider narrower channels than those originally proposed. It was decided that a set of alternative channel widths for each channel reach would be studied. These alternatives are listed below.

a. Widths of 450 ft or 550 ft in the Entrance Channel.

b. Widths of 500 ft or 600 ft in the Horn Island Pass Channel.

c. Widths of 350, 300 or 250 ft in the Main Pascagoula and Bayou Casotte Channels.

Appropriate bend widenings would accompany each of the alternatives. Another modification to the feasibility proposal involves sediment impounding basins in the Entrance Channel. The basin in the reach adjacent to Petit Bois Island will be expanded to stretch along the eastern side of the channel throughout the southern half of the pass. An additional impounding basin will be constructed on the eastern side of the Entrance Channel to compensate for localized shoaling which has encroached into the channel recently. The depths of the impounding basins are proposed to be the same as the channel depth in the area. The other details of the proposal in the Feasibility Report would remain unchanged, such as, the proposed channel depth and the design of the proposed turning basin in the Bayou Casotte harbor. Figure 2 shows the entire study channel as implemented in the simulator, the insets show critical areas in greater detail.

Scope of Simulator Study and Test Design

A particular concern affecting new channel construction was the presence of petroleum pipelines crossing the Pascagoula and Bayou Casotte Channels in three separate locations (see Figure 2). Originally, it was thought that for a nominal 350-ft width the channel could be narrowed to 300 ft at these locations without pipeline relocation. One scenario was included in the simulation test program which tested navigability of this channel narrowing through the two pipeline crossings in the Pascagoula Channel.

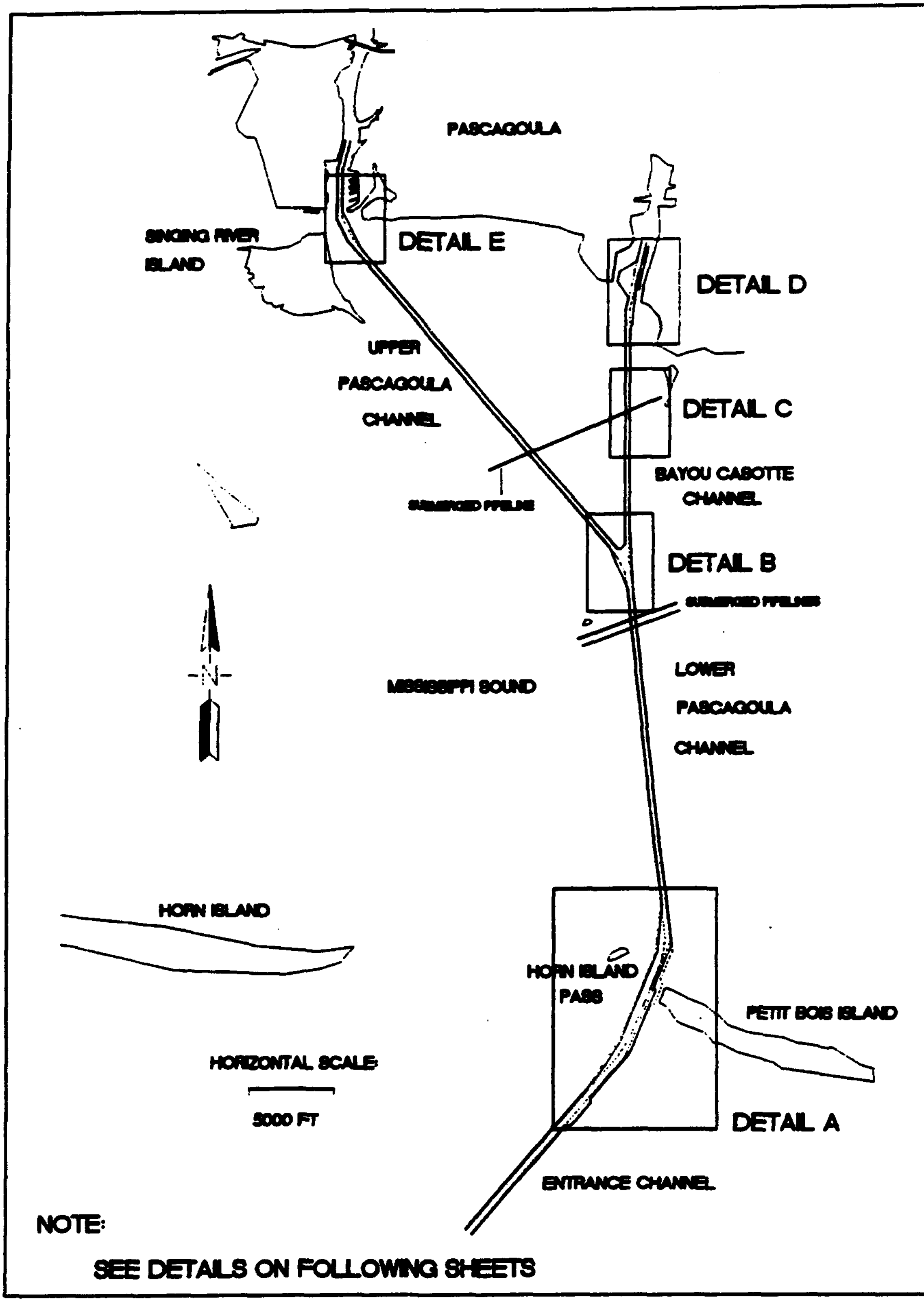

Figure 2a. Study channel as implemented in the simulator

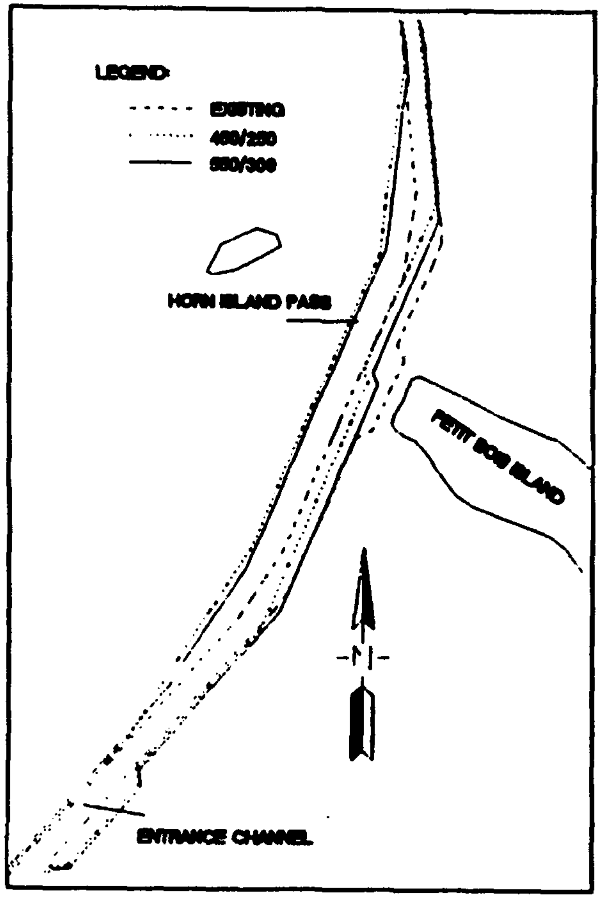

Figure 2b. Detail A of Figure 2a

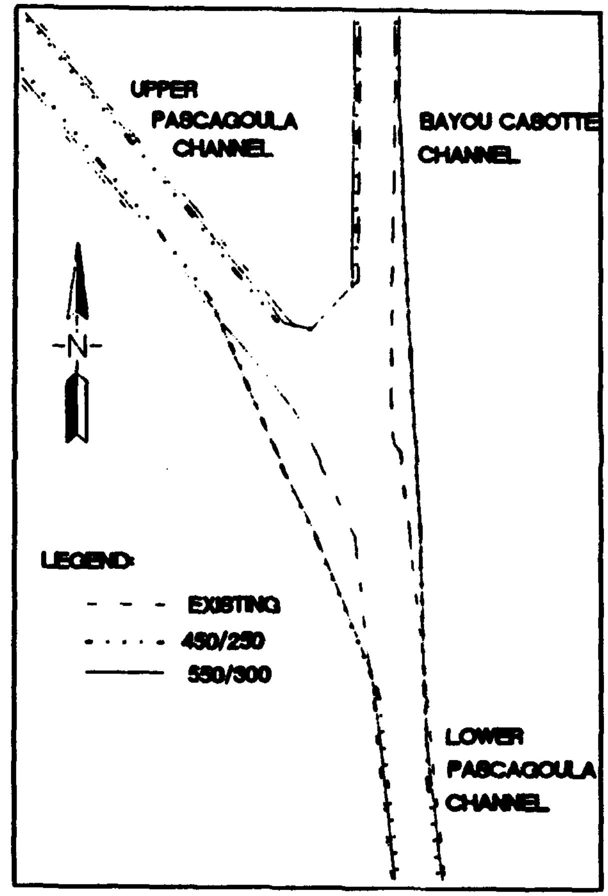

Figure 2c. Detail B of Figur

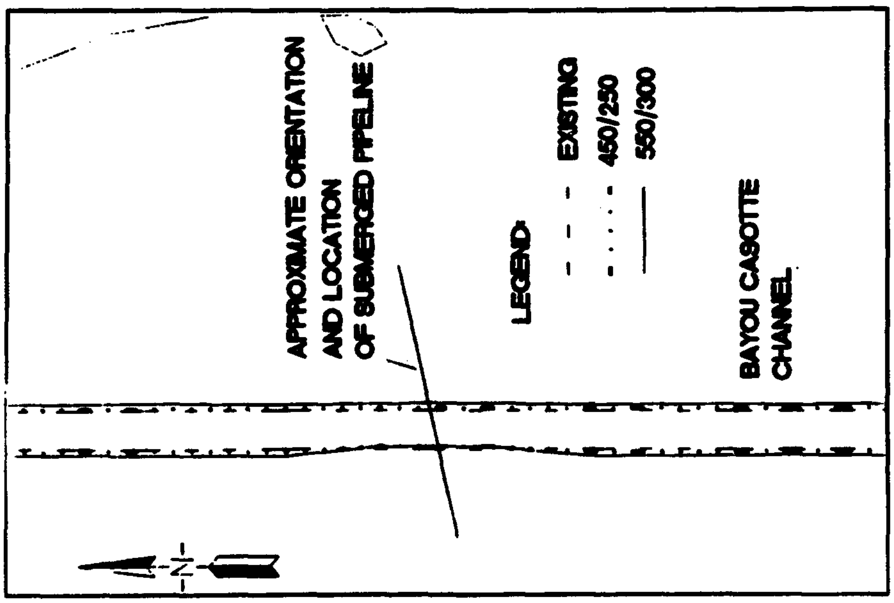

Figure 2d. Detail C of Figure 2a

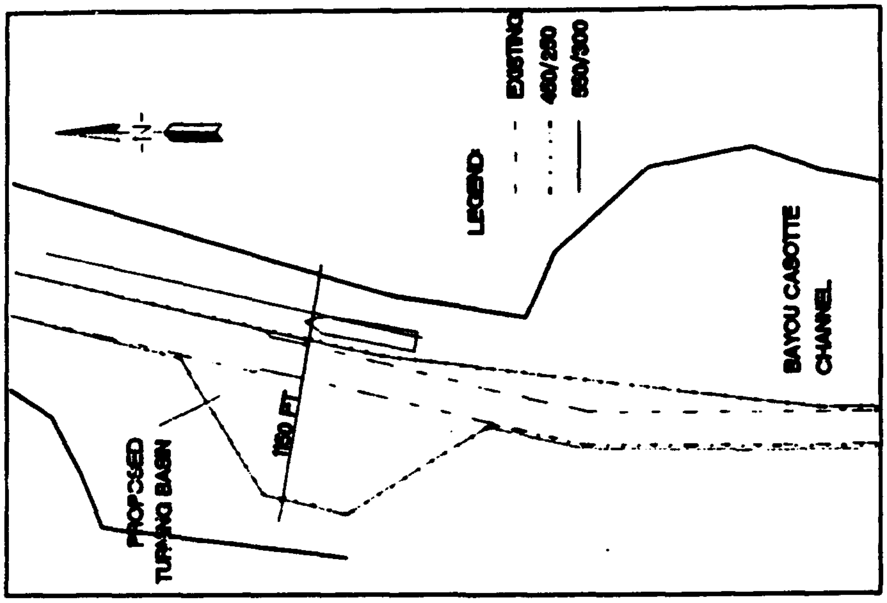

Figure 2e. Detail D of Figure 2a

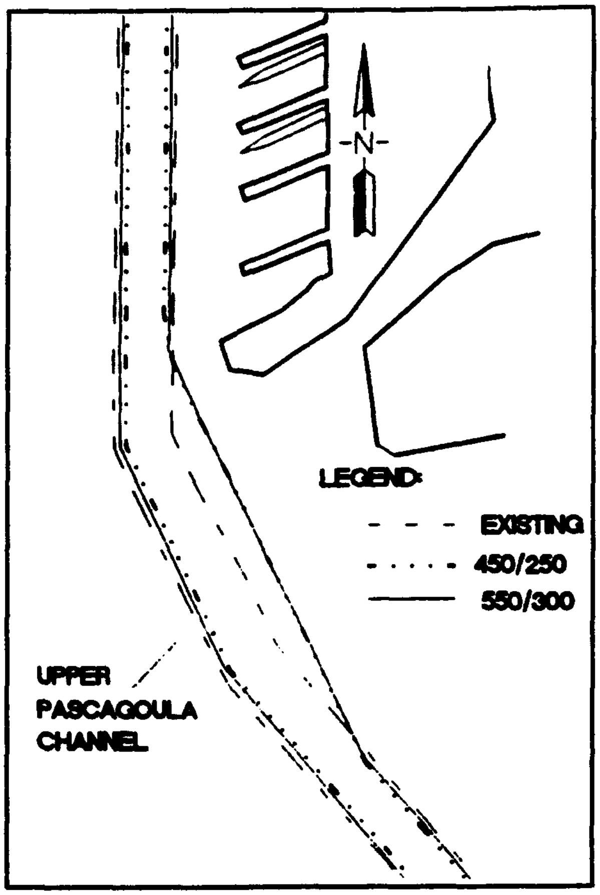

Figure 2f. Detail E of Figure 2a

After the start of pilot testing, elevation surveys obtained by the District showed that the pipelines at these two locations would, indeed, require relocation for any channel width prior to deepening. For the other pipeline crossing, in the Bayou Casotte Channel, the District determined that if the channel could be narrowed only on the western side without affecting vessel navigation then the pipeline would not have to be relocated. This new information led to a change in test conditions during the study. The original test of the pipeline constrictions in the Pascagoula Channel was dropped and discussions concerning the results will not be presented in this report. The alignment for the Bayou Casotte Channel was changed for the remainder of the simulation tests to reflect a western-side narrowing at the pipeline crossing.

With many channel configurations and natural conditions to be considered, it was important to streamline and design the simulation study to test the worst case. It was considered not practical to test all combinations of the individual channel segment widths listed above. This reasoning lead to the implementation of two basic proposed channel configurations in the simulator.

First, the 450-ft width in the Entrance Channel was combined with the 500-ft width in Horn Island Pass and the 250-ft width in the inner channel segments. Second, the 550-ft width in the Entrance Channel was included with the 600-ft width in Horn Island Pass and the 300-ft width in the inner channels. The 350-ft width for the inner channel segments was not actually tested but was considered the "default", to be recommended in the event that the narrower widths proved inadequate for safe and efficient navigation. In addition to these tests, the proposed turning basin at the southern end of the Bayou Casotte Inner Harbor required investigation. The proposed turning basin was designed to provide a more convenient turning area for the oil tankers leaving the oil refinery. As discussed earlier, at present, these tankers must turn in the existing basin at the landward end of the Bayou Casotte Channel. Even though the proposed turning basin will be located in protected waters, some maneuvering difficulty can be expected in the event another tanker is moored at the oil refinery dock adjacent to the eastern side of the basin; therefore, the simulation scenario included a tanker in this position.

Ambient environmental conditions varied between different scenarios. For example, wind was included in scenarios involving LASH ships because the ships themselves have a large "sail" area and are affected by wind rather severely, the result of which could be critical to the design of channel width. In addition, during the initial simulation tests with the LASH ship an hour of the tidal cycle was chosen which had the maximum cross-channel currents in the Main Channel in the Mississippi Sound. This combination of cross wind and current and the very long LASH ship constituted a critical set of conditions for the simulations, especially for the sound portion of the channel. For inbound runs with tankers and bulk carriers, maximum ebb tide was used. For the loaded outbound bulk carrier runs from the Pascagoula River maximum flood tide was used. A list of conditions for each of the scenarios tested in the simulation study is presented later in tabular form.

2 Data Development

Required Data

Data required for the conduct of the simulation study included channel geometry, bottom topography, channel currents for proposed as well as existing conditions, numerical models of test ships and visual data of the physical scene in the study area. Dredging survey sheets provided by Mobile District were used for the existing channel alignment and the proposed channel alignment was modeled as designed. A two-dimensional depth-averaged finite element numerical current model was generated at WES using the TABS-2 system. A reconnaissance trip was carried out for the purpose of observing actual shipping operations in the study area. Video recordings and still photographs were taken during the transits to aid in the generation of the simulated visual scene. Discussions with pilots were also held during this trip so that WES engineers could become more familiar with concerns and problems experienced during operations. Numerical models of the test ships were developed through a contract with Tracor Hydronautics, Inc.

Description of Simulator

It is beyond the scope of this report to describe in detail the WES ship simulator; however, a brief explanation will be made. The purpose of the WES ship simulator is to provide the essential factors necessary in a controlled computer environment to allow the inclusion of the man-in-the-loop, i.e., local ship pilots, in the navigation channel design process. The simulator is operated real-time by a pilot at a ship's wheel placed in front of a screen upon which a computer generated visual scene is projected. The visual scene is updated as the hydrodynamic portion of the simulator program computes a new ship's position and heading resulting from manual input from the pilot (rudder and engine throttle commands) and external forces. The external force capability of the simulator includes effects of wind, waves, currents, banks, shallow water, passing ships and tug boats. In addition to the visual scene, pilots are provided with simulated radar and navigation information which includes water depth, relative ground and water speed of the vessel, magnitude of lateral vessel motions, relative wind speed and direction, and ship's heading.

Validation and Data Description

One of the most important milestones in the simulation process is the validation exercise. During this exercise pilots from the study area come to WES to conduct simulator tests in existing conditions. The purpose of the tests is to use local pilot expertise to ensure that the simulation is as realistic as possible. While conducting these tests the pilots pay close attention to ship handling, external force effects and visual scene objects and make comments and recommendations for improvement. Validation tests usually result in some modifications to the data bases. The five input data bases required to conduct a simulation study for a particular channel are listed below and discussed as related to the Pascagoula study.

Test file

The test file contains initial conditions (ship speed and heading, rudder angle and engine setting) for the simulation and geographical coordinates for the channel alignment. The channel is defined in terms of cross sections located to coincide with changes in channel alignment and current direction and magnitude. The information used for the development of the Pascagoula channel data base was obtained from USAED, Mobile's project drawings. On these drawings the alignments for the existing and proposed channels were overlaid upon soundings of hydrographic survey data. The Mississippi state plane coordinate grid was also plotted on these drawings and was used for simulator data base definition. Also included in the test file is the steepness and height of the banks adjacent to the channel. This data is used by the computer to calculate bank suction forces on the test vessels. Specifications of other external forces such as wind and waves are also included in this file. Also, the definition of the autopilot track-line and commands which enable the autopilot are included for use in the simulator's fast-time capability.

For the Pascagoula project the simulator channel cross sections were placed so as to mark each bend of the channel and delineate changes in channel width, e.g., where a turning basin opens up on one side of the channel. In straight sections of the channel where currents changed slowly the cross sections were spaced fairly widely. Closer spacing was used in critical current regions such as in the Horn Island Pass and in the entrance into the Pascagoula River. The WES simulator model does not allow branching channels; therefore, a separate data base had to be constructed for both the Pascagoula and Bayou Casotte Channels. See Figure 2 for comparisons of the different test channel alignments.

Water depths for the simulator were based on authorized project depths. For the simulated existing channel, the water depth represented the approximate existing condition taken from the most recent dredging survey furnished by the district. In the proposed conditions a 4-ft deepening was

applied to the channel depth resulting in a 42-ft depth in the inner channels and a 44-ft depth in the Entrance Channel. Existing depths were maintained in the proposed channels when they were deeper than the proposed depths.

In many channels, especially narrow ones such as the Pascagoula channels, bank suction becomes a critical factor during ship navigation. As a brief explanation, bank suction occurs when a vessel travels close to a bank (also, a wall or a moored ship) causing the vessel to be simultaneously subjected to a translational force directed toward the bank and a rotational force turning the bow away from the bank. This occurs because of decreased flow area between the ship and the bank resulting in increased water velocity and decreased hull pressure along the side of the ship closest to the bank. As an example of this phenomenon, during the reconnaissance trip to the study area one of the pilots remarked that steering difficulty occurs because of bank suction when steering a loaded outbound bulk carrier through the intersection of the two main channel branches. This is most likely a result of the nonsymmetry of high submerged banks on the western side of the channel and a wide opening to the Bayou Casotte Channel on the eastern side. The WES simulator uses an empirical approach in calculating bank forces based on vessel draft to water depth ratio, vessel speed, distance of vessel from both banks, bank slope and depth of water at the top of the bank. Input in the test file includes the last two parameters. For the Pascagoula channels these data were obtained from the dredging survey sheets.

Input in the test file also includes imposed wind conditions. For the Pascagoula Harbor simulation, wind was used only for those tests conducted with the LASH ship because wind has a negligible effect on loaded tankers and bulk carriers. The magnitude and direction of the wind was decided upon during discussions with the validation pilot concerning critical conditions. Since the wind force calculation in the simulator was not calibrated, it was decided that the wind magnitude should be lowered until the pilot felt it was realistic. This procedure resulted in an easterly wind at 15 knots.

Scene file

The scene data base is comprised of several data files containing geometrical information which enables the graphics computer to generate the simulated scene of the study area. The computer hardware and software used for visual scene generation is separate from the main computer of the ship simulator. The main computer provides motion and orientation information to a stand-alone graphics computer for correct vessel positioning in the scene which is then viewed by the pilot. Operators view the scene as if they are standing on the bridge of a ship looking out the window with the ship's bow in the foreground. View direction can be changed during simulation for the purpose of looking at objects outside of the relatively narrow straight-ahead view.

Aerial photographs, navigation charts and dredging survey charts provided the basic data for generation of the visual scene. The simulation testing required low visual resolution beyond the immediate vicinity of the navigation channel. All land masses in the vicinity of the navigation channel were included in the scene, comprised of the mainland, emergent islands in the sound and the barrier islands of Petit Bois and Horn. All aids to navigation in the vicinity of the study area were included. Man-made features in the inner harbors which were in the visual scene included docks, buildings and moored petroleum drilling rigs. Docked ships were included in the scene at the Ingalls Shipbuilding, Inc. installation in the Pascagoula River and at the Chevron oil refinery in the Bayou Casotte Harbor.

In addition to the man-made and topographical features in the study area, the visual scene includes a perspective view of the bow of the ship from the pilots viewpoint. Bows for both the design bulk carriers and design tanker were already available at WES for inclusion in the simulation. However, a visual representation of the LASH ship had to be generated for the project. Because the pilot house is positioned at the front of a LASH ship, very little could be seen of the bow in the forward view of the simulator projection.

Radar file

The radar file contains coordinates defining the border between land and water and significant man-made objects, such as, docked ships and aids to navigation. These data are used by another graphics computer which connects the coordinates with straight lines and displays them on a terminal. The objects viewed comprise visual information which simulates shipboard radar. The main information source for this data base was the project drawings and dredging survey sheets supplied by the district.

Ship files

The ship files contain characteristics and hydrodynamic coefficients for the test vessels. These data are the computer's definition of the ship. These coefficients govern the reaction of the ship to external forces and internal controls, such as wind, current, waves, banks, underkeel clearance, rudder and propeller rpm. The numerical ship models for the Pascagoula simulations were developed by Tracor Hydronautics, Inc. of Laurel, Maryland. New models were developed for the LASH ship and the Schilling tanker and existing models were modified for the two bulk carriers. Numerical models for the LASH ship (*Stonewall Jackson*) and bulk carriers (*El Gaucho* and *Delaware*)

are presented in Ankudinov 1988[1] and Ankudinov 1989[2] presents the development of the model for the Schilling tanker (*R. Hal Dean*). For the present study the test ships were chosen based on discussions with District personnel, WES personnel and Pascagoula pilots. For quick reference, Table 1 lists the important characteristics of these ships. Figure 3 depicts representative profiles of the five ship types used during the simulation study.

Table 1
Ship Characteristics for Pascagoula Simulation Study

Ship Name	Ship Type	LOA (ft)	Beam (ft)	Draft(s) (ft)	Tonnage (tons)
Stonewall Jackson	LASH	894	100	34/36	46,000
El Gaucho	Bulk carrier	775	106	36	59,000
Delaware	Bulk carrier	850	106	40	87,000
Unknown	Tanker	810	125	28/36/40	87,000
R. Hal Dean	Tanker	784	122	36/40	78,000

Current file

The current file contains current magnitude and direction and water depth for each of eight points across each of the cross sections defining the channel alignment. Current data for a ship simulation study is usually obtained from one of two sources: physical or numerical models. Fiscal constraints and/or availability usually dictate which of the two sources is used for a particular simulation project. Numerical modeling of currents is preferred over physical modeling because higher resolution is obtainable. For the Pascagoula simulation study a finite element model was developed in the Estuaries Division at the Hydraulics Laboratory using the TABS-2 modeling system. A spring tidal range of approximately 2.5 ft and a 20 knot easterly wind were used as test conditions for the current model. In addition, a freshwater in-flow from the Pascagoula River was included. Boundary conditions for the TABS-2 model were generated from a low resolution finite difference model of the Mississippi Sound. This model had been used in a previous circulation study of the Mississippi Sound and was modified and rerun with the aforementioned boundary conditions by Dr. Donald Raney at the University of Alabama.

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[1] Ankudinov, V. (1988). "Hydrodynamic and mathematical models for ship maneuvering simulations of 'LASH' barge carrier and two bulk carriers in support of the Pascagoula Harbor study," TR 87005.0623-1, Tracor Hydronautics, Inc., Laurel, Maryland.

[2] __________. (1989). "Hydrodynamic and mathematical models for ship maneuvering simulations of lightering vessel equipped with the Schilling rudder in support of the Pascagoula Harbor study," TR 87005.0923-1, Tracor Hydronautics, Inc., Laurel, Maryland.

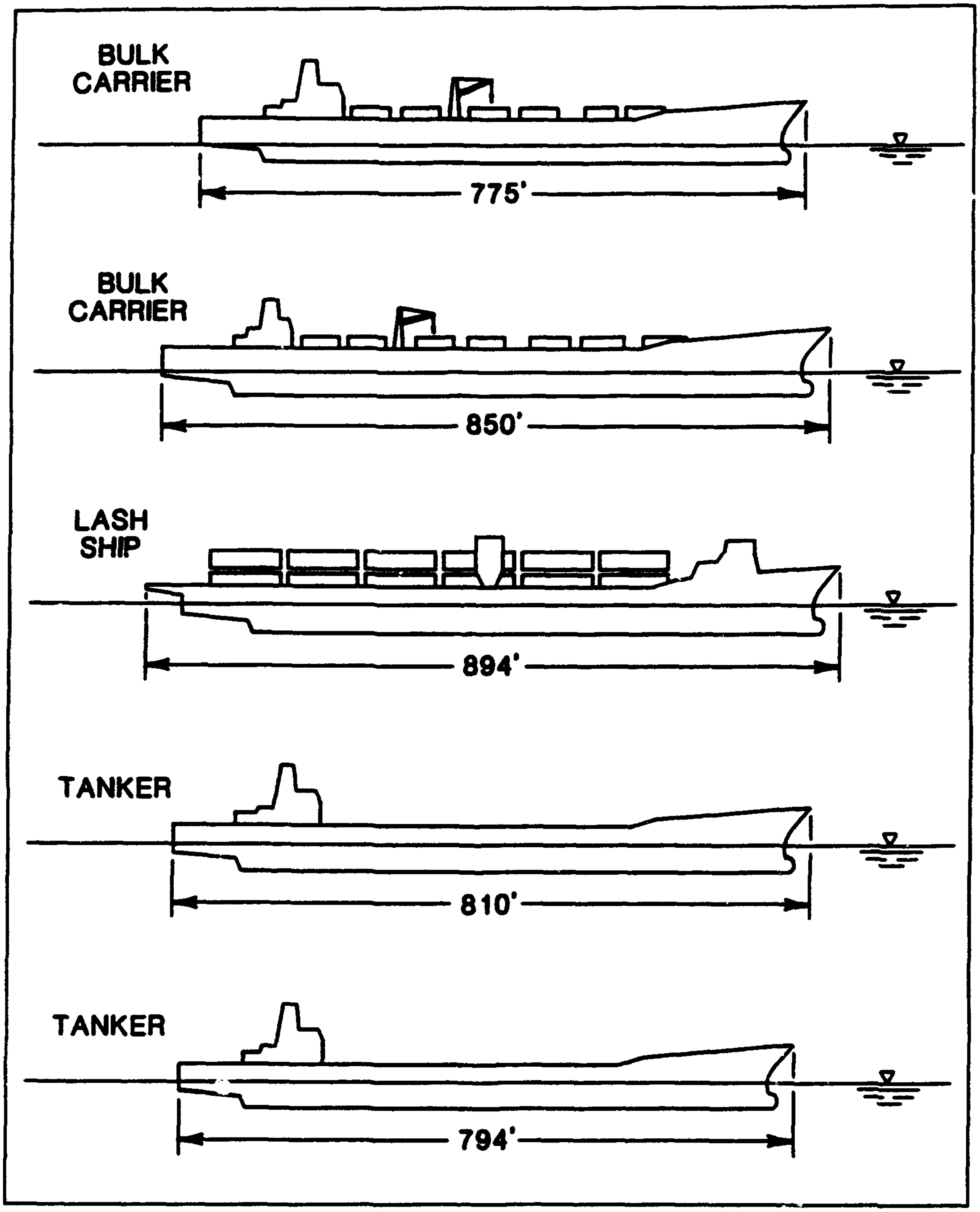

Figure 3. Profile of ships used in Pascagoula simulation study

In the current model development process, assurance was made that the boundary of the TABS-2 finite element grid aligned with existing grid lines of the Mississippi Sound finite-difference model. For numerical model verification, a field survey crew from WES traveled to the Pascagoula area on 1 & 2 June, 1988 to obtain prototype current data during a period of spring tide. Using the data measured during the field exercise, model verification was done for existing channel conditions. With the verified model, production runs were made for the three channel alignments listed earlier in the section for simulator test conditions. From these production runs three current conditions were extracted to be tested in different scenarios in the pilot testing program. These three conditions were flood tide at maximum current speed, ebb tide at maximum current speed and a mid-tide condition at the time when channel cross currents in the Lower Pascagoula Channel were maximum. It should be noted that because current data were extracted from the hydrodynamic model in snapshots at particular tidal phases, peak currents do not necessarily coincide in different areas of the channel in the simulator current data bases. The depth-averaged current speed for the maximum cross current condition was generally less than 0.5 knot and for the ebb and flood conditions the greatest current speed was approximately 1.25 knots in the Horn Island Pass area. Figures 4-9 show the current vectors for some of the most critical areas. The entire channel cannot be shown because of space limitations; however, in the straight segments during the maximum ebb and flood conditions the currents are generally aligned with the channel. In the same areas the current direction during the maximum cross current condition was almost perpendicular to the Lower Pascagoula and Bayou Casotte Channels.

Table 2 below summarizes the test scenarios conducted during the initial simulations. Table 3 lists the scenarios tested during the entrance area simulations conducted subsequent to those in Table 2.

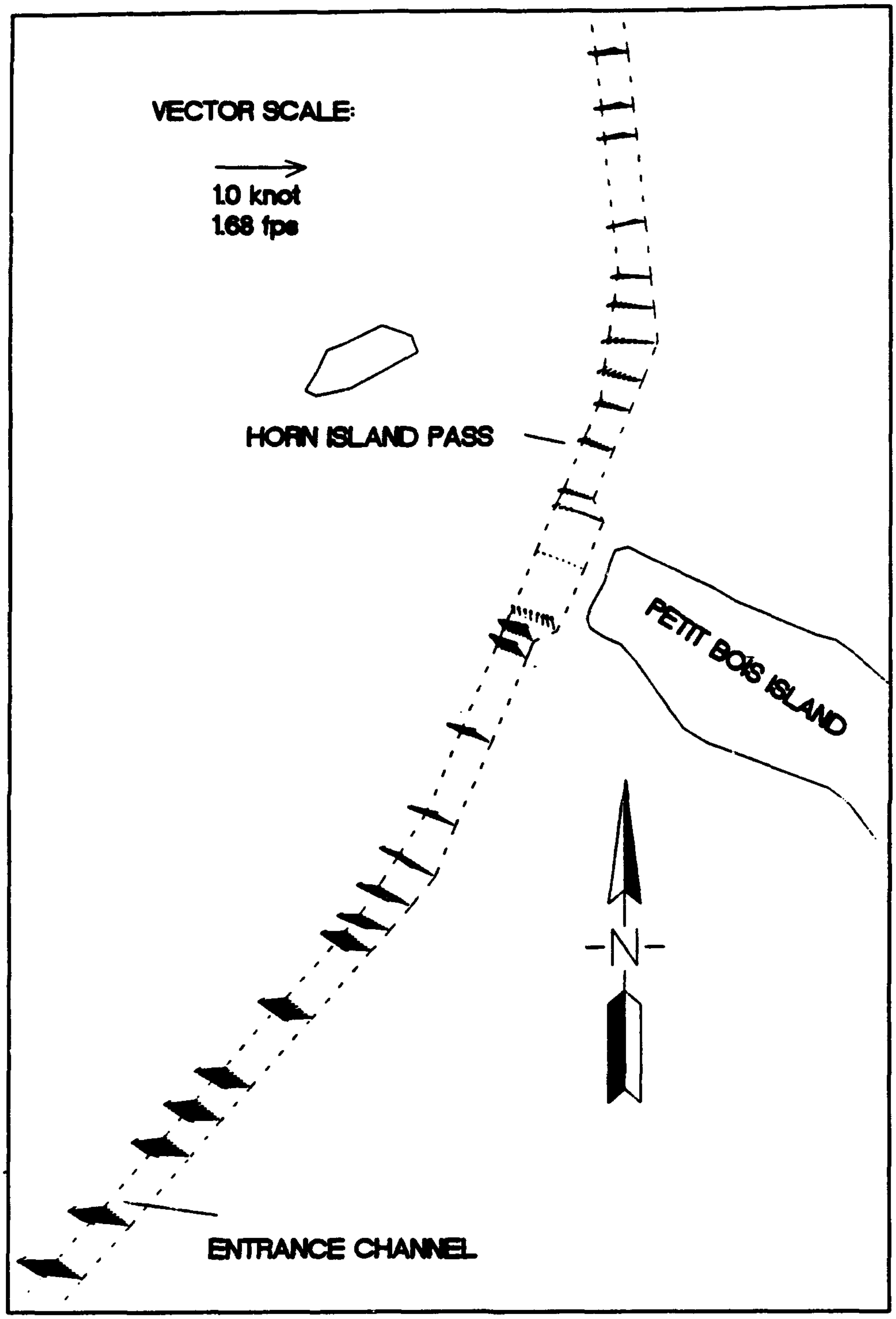

Figure 4. Maximum cross current, Horn Island Pass

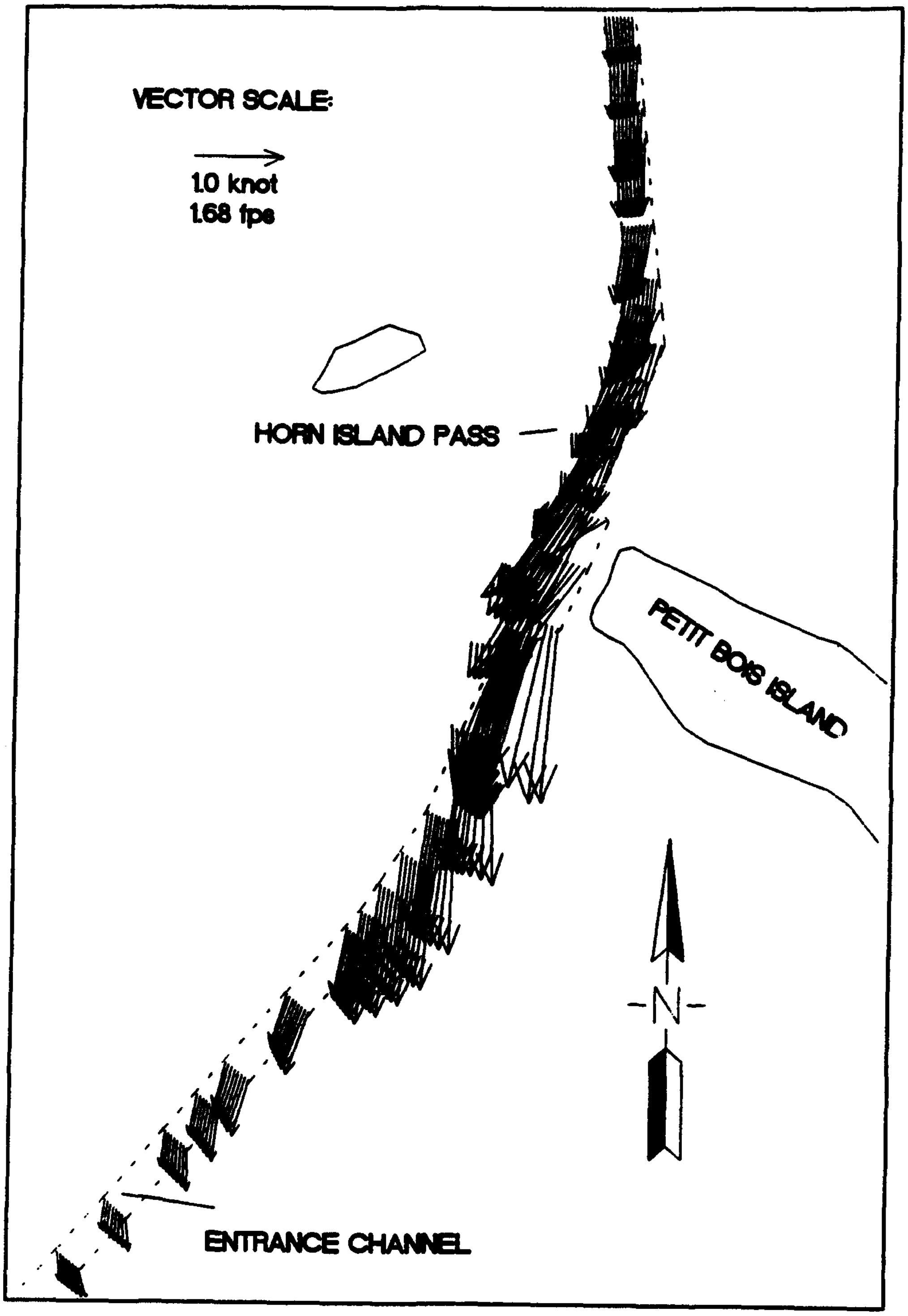

Figure 5. Maximum ebb current, Horn Island Pass

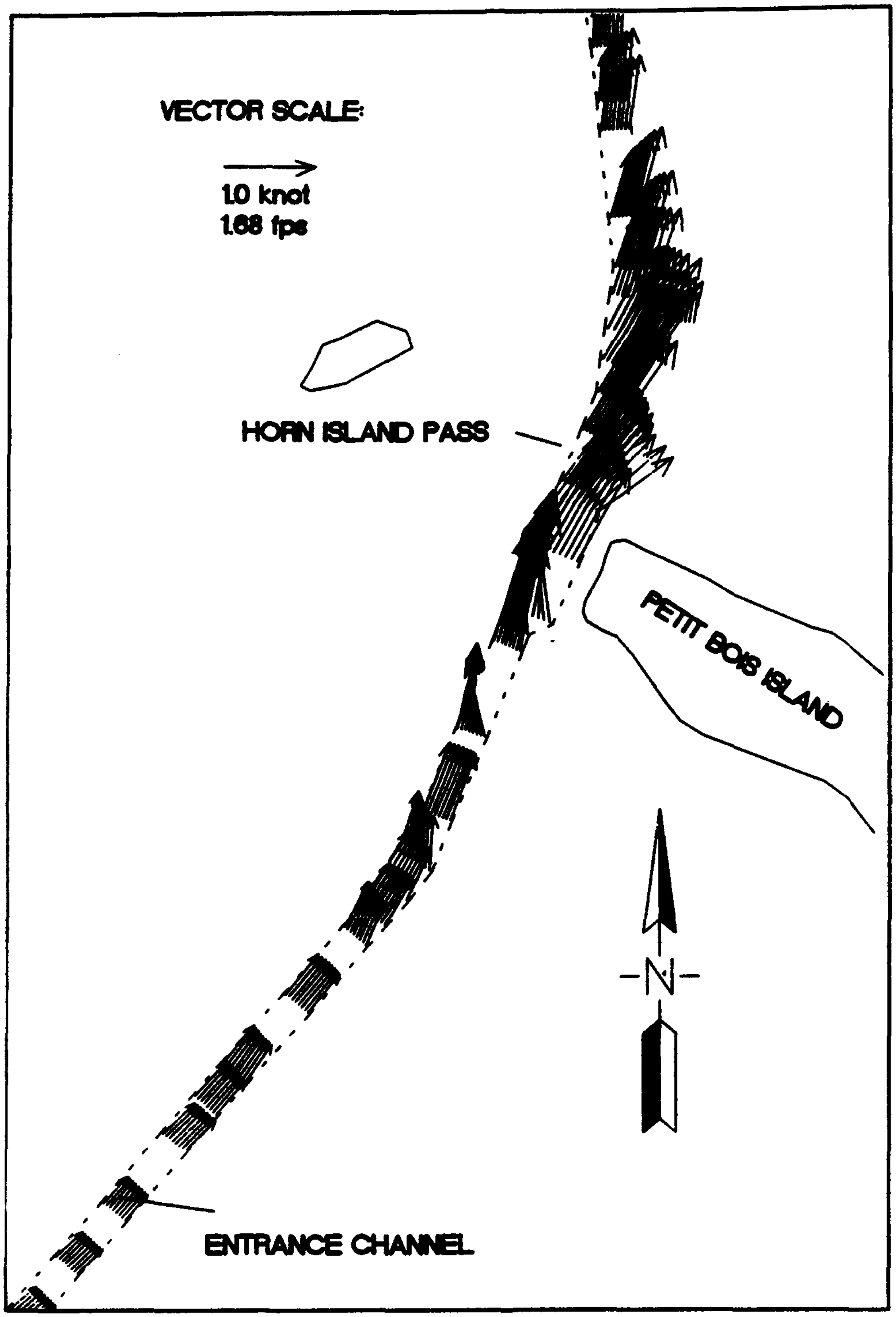

Figure 6. Maximum flood current, Horn Island Pass

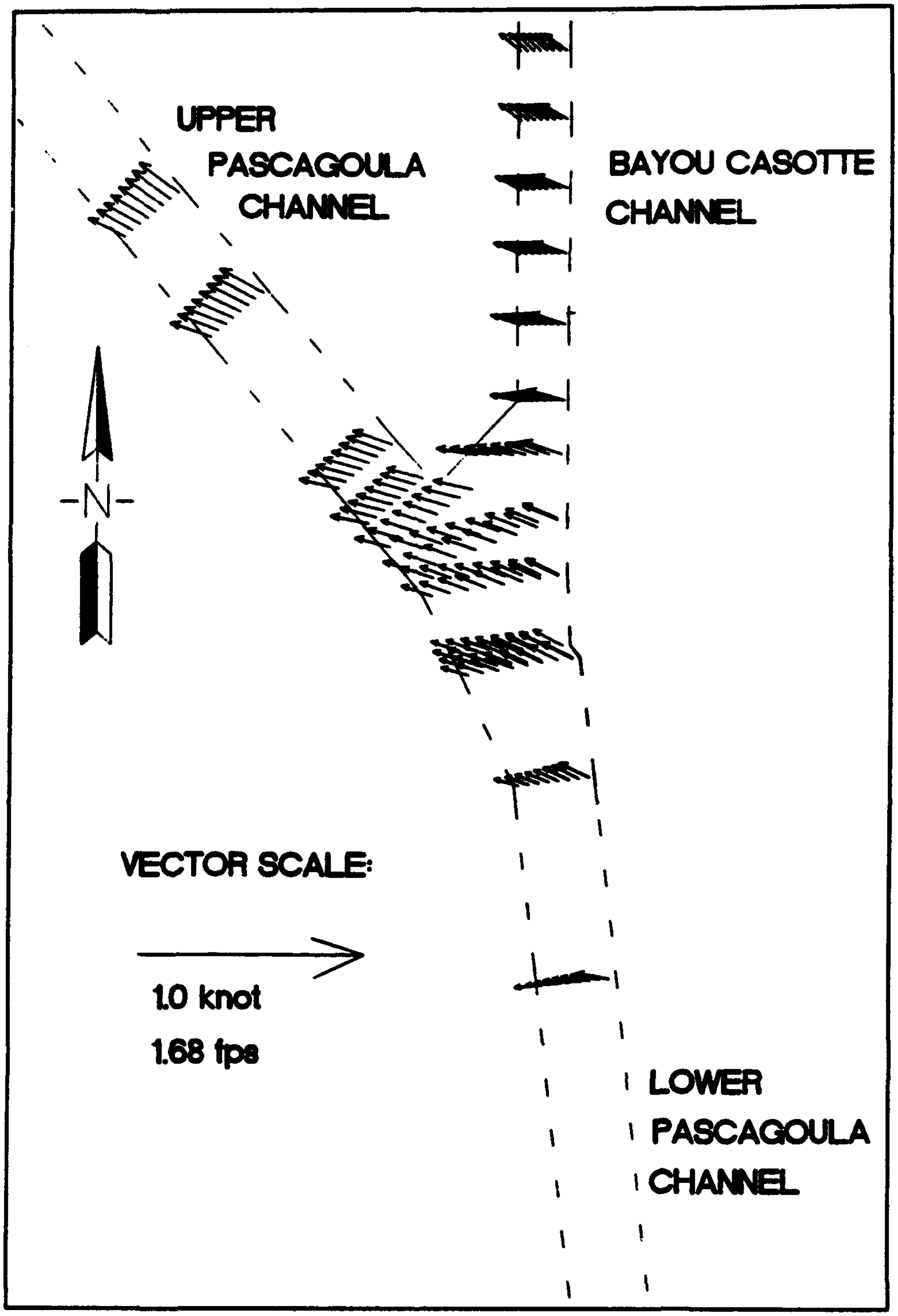

Figure 7. Maximum cross current, channel intersection

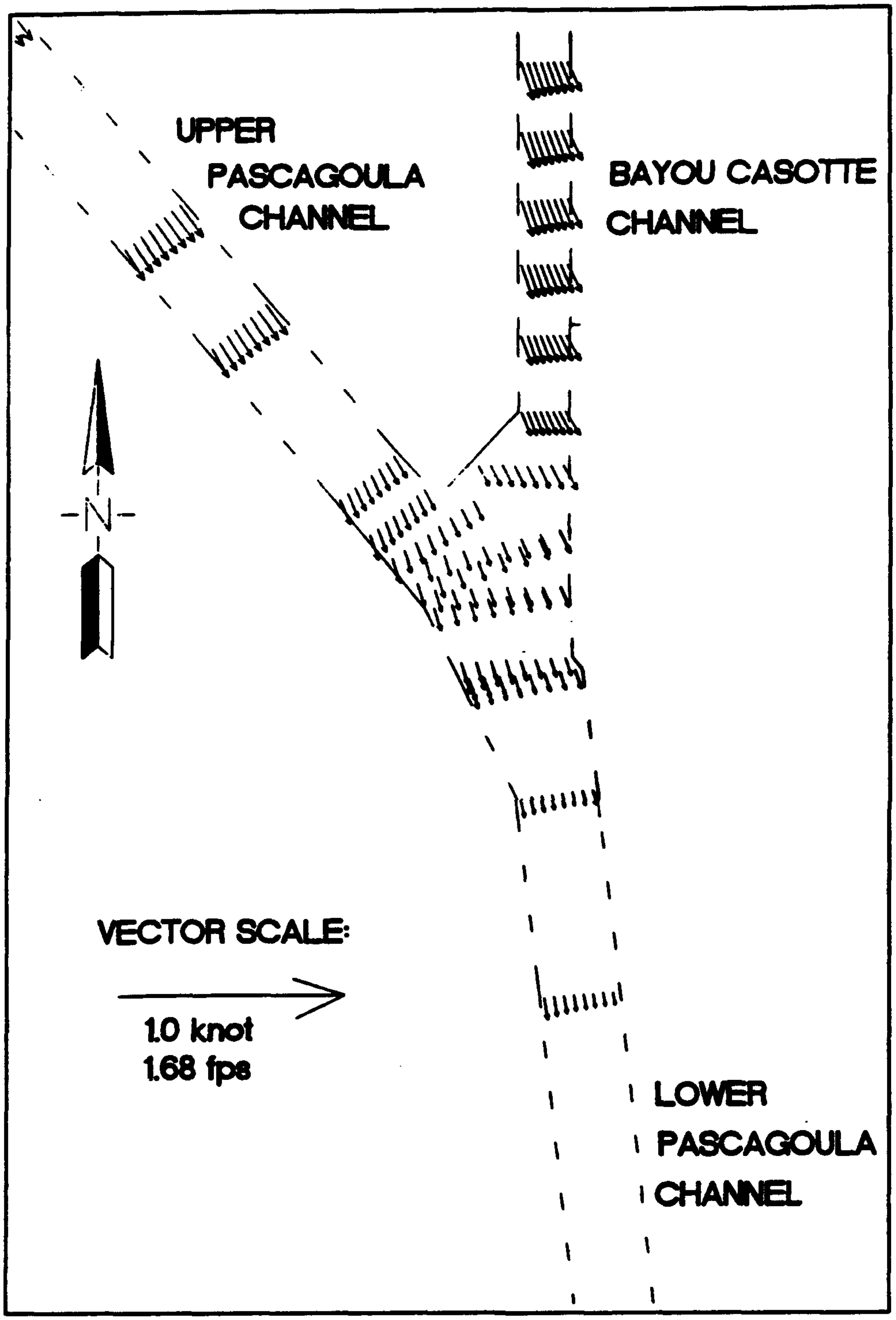

Figure 8. Maximum ebb current, channel intersection

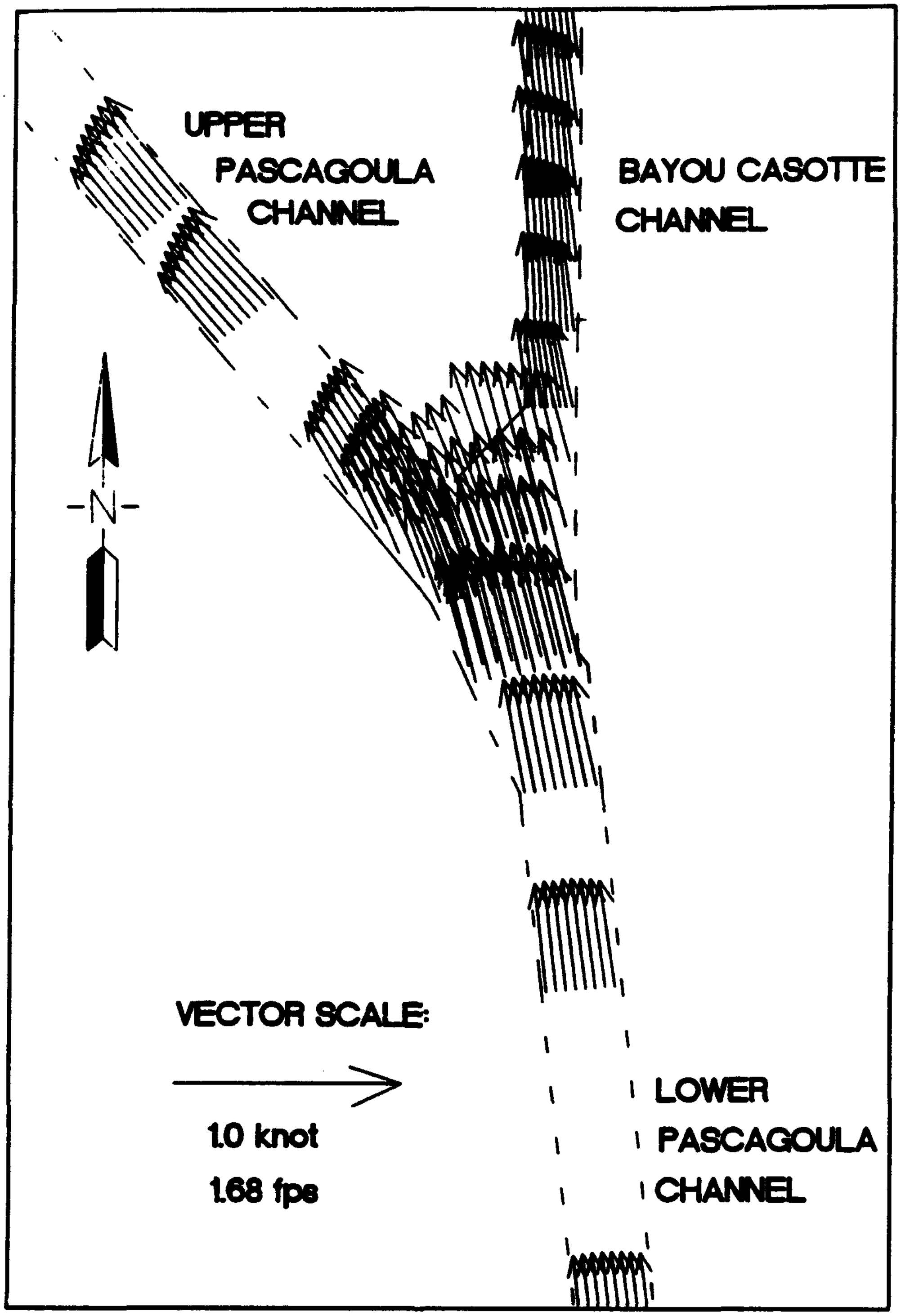

Figure 9. Maximum flood current, channel intersection

Table 2
Test Scenarios for Initial Pascagoula Simulations

Scenario No.	Test Channel	Test Reach	Direction	Test Ship	Test Current	Test Wind
1	Existing	Petit Bois to Bayou Casotte	Inbound	Tanker 87K DWT 36 ft draft	Maximum ebb	East 15 knots
2	450/250			Tanker 87K DWT 40 ft draft		
3	550/300					
4	Existing	Sea Buoy to Bayou Casotte		LASH ship 46K DWT 34 ft draft	Maximum cross current	
5	450/250			LASH ship 46K DWT 36 ft draft		
6	550/300					
7	Existing	Upper Pascagoula Channel		Bulk carrier 59K DWT 36 ft draft	Maximum ebb	0
8	450/250			Bulk carrier 87K DWT 40 ft draft		
9	550/300					
10	Existing	Pascagoula River to Sea Buoy	Outbound	Bulk carrier 59K DWT 36 ft draft	Maximum flood	
11	450/250			Bulk carrier 87K DWT 40 ft draft		
12	550/300					
13	450/250	Bayou Casotte Turning Basin		Tanker 87K DWT 26 ft draft	0	

Table 3
Test Scenarios for Pascagoula Entrance Area Simulations

Scenario No.	Test Channel	Time of Day	Test Reach	Test Ship	Test Current
1	Existing	Day	Entrance channel	LASH ship 46K DWT 34 ft draft	Maximum ebb
		Night			
2		Day		Tanker Schilling 36 ft draft	
		Night			
3	450/250	Day		LASH ship 46K DWT 36 ft draft	
		Night			
4		Day		Tanker Schilling 40 ft draft	
		Night			
5	550/300	Day		LASH ship 46K DWT 36 ft draft	
		Night			
6		Day		Tanker Schilling 40 ft draft	
		Night			
7	Recom.	Day		LASH ship 46K DWT 36 ft draft	
		Night			
8		Day		Tanker Schilling 40 ft draft	
		Night			

3 Test Results

Organization of Discussion

As discussed in the introduction, the Pascagoula simulation study consisted of two series of pilot tests: the initial tests and the entrance area tests. The entrance area tests actually resulted in a modification of the recommendations presented in the preliminary letter report concerning the initial simulation tests. The results for both test series are presented in this report with a summarization of the composite recommendations in the last section.

Initial Pascagoula Simulations

After the first pilot visited WES for the purpose of validation, five more professional pilots from Pascagoula visited WES for simulator testing of the scenarios shown in Table 1. Because of the length of the runs involved generally only one run per pilot per scenario was obtained. The exception was scenario #13, the turning basin test, for which two runs were completed by most of the pilots. During the course of the test program it became necessary to make two modifications to the data bases. The initial channel setup included submerged banks with a constant slope angle for the proposed channels. The slope angle used was given by the district as part of their construction specifications; and, therefore, represented an ideal channel geometry. There was some indication during testing with the first pilot that the modeled constant bank slope angle was causing the bank suction and shear to be too predictable and unrealistic. Before the second pilot came the bank angles in the proposed channels were changed to the same values as in the existing channel thereby creating a more realistic model. The remainder of the pilots were tested in this modified channel geometry. The second modification involving the submerged pipeline which crosses the Bayou Casotte Channel has already been discussed earlier. After the first three pilots completed their testing, the results of the pipeline elevation survey was received and the proposed alignment of the Bayou Casotte Channel was changed in the simulator to include a constriction around the pipeline on the western side of the channel only. This was designed to test the effect of an asymmetric constriction on navigation in the event that the pipeline proved too costly to be relocated. Subsequent to pilot testing it was determined that the tracklines of

the pilots before and after these modifications were similar enough to combine the results on the same plot. Therefore, the figures to be discussed below show the results of all five pilots.

Trackline and Control Measures Analysis

Proposed Bayou Casotte turning basin

Figure 5 shows the results from the simulator testing in the proposed turning basin in the Bayou Casotte Harbor (scenario #13 on Table 2). The composite consists of eight individual runs with three of the pilots contributing two runs each and the other two pilots contributing only one each. The proposed turning basin will be located in a sheltered area and the simulation test was conducted under calm and slack conditions. The test was designed to simulate one of the most difficult of the possible future turning operations with the test ship leaving the dock at the most northern of two adjacent berthing areas and backing into the basin while avoiding another tanker moored at the other dock. The proposed turning basin was delineated in the simulator visual scene and radar by four markers located on the periphery. During the simulation tests the general practice of the pilots was to start the maneuver with two 3500 hp tugs on the port side pulling the ship westward. Once the dock had been cleared the pilots reversed the ship's engine and backed into the basin using the tugs to control rotation. When within the basin one of the port-side tugs was usually shifted to the starboard side to complete the turn. On a few runs the turn was accomplished using only one tug for the completion of the turn. After the turn the pilots then entered the channel as they would for an outbound transit. It is evident from the figure that for two of the runs the vessels came fairly close to the moored ship. One of these actually completed the turn too close to the docked ship, in the other one the stern of the tanker swung fairly close to the other ship as the pilot proceeded outbound. This is considered a result of the location of the turning basin in relation to the bend at the entrance to the Bayou Casotte Harbor. This configuration forced the pilots to steer the vessel in an S-turn in order to reenter the channel from a position inside the turning basin, thereby causing the stern to swing out and approach the moored tanker. The recommended alleviation of this problem is to enlarge the basin by modifying the southern boundary to be located along a line between turning basin marker #2 (see Figure 10) and the existing channel marker just to the south of turning basin marker #1. This change would eliminate the need for the S-turn into the channel and would position the turning vessel farther away from an adjacent docked ship.

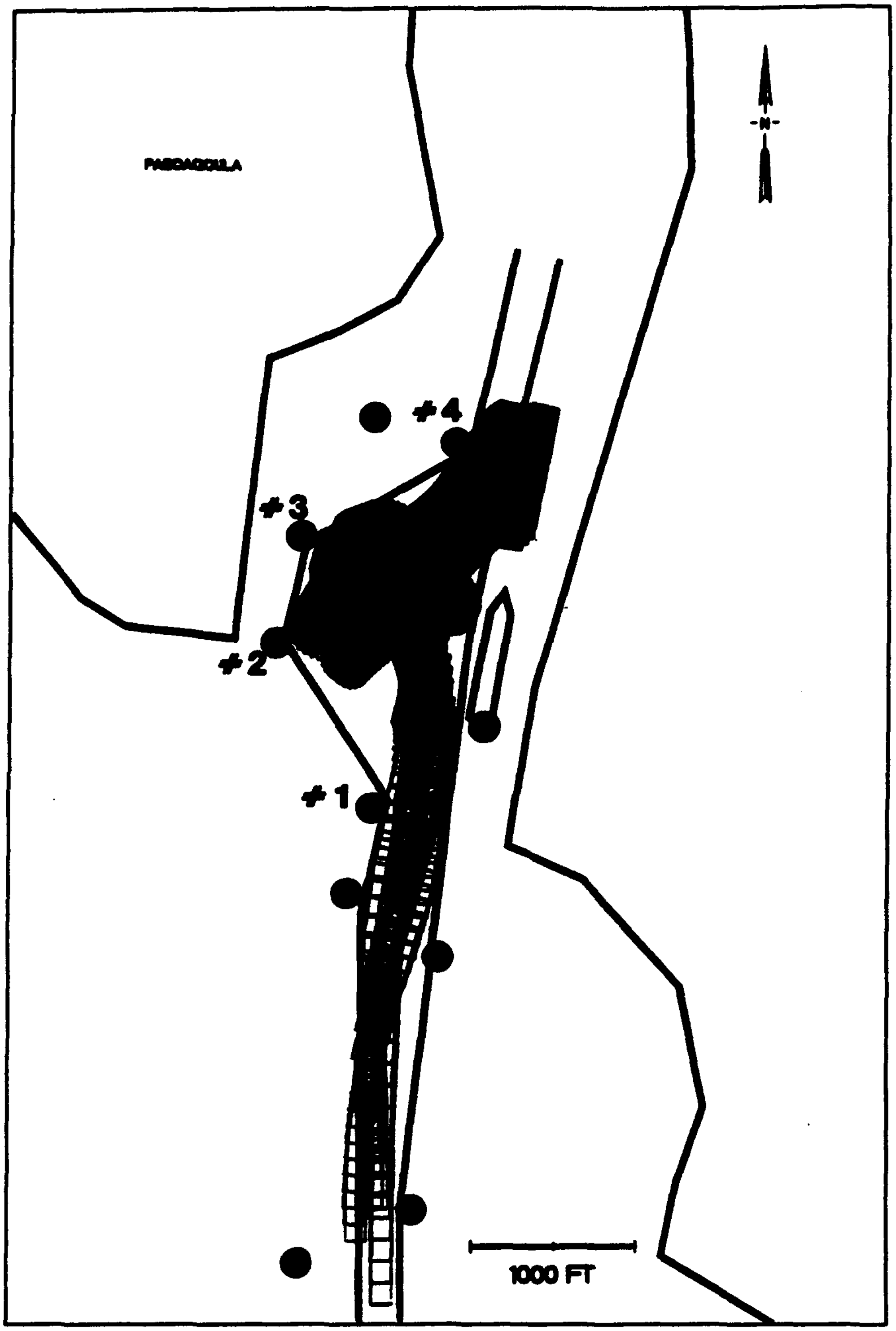

Figure 10. Composite pilot tracklines, Bayou Casotte turning basin 450/250 channel, tanker (810x125x26), no current, no wind, tug assist

LASH ship runs

Figures 11-13 show the composite pilot tracklines for the inbound runs with the LASH ship. On Figure 11, the existing channel runs (scenario #4, Table 2), the plot for the first reach shows that all the pilots kept to the western edge of the channel in order to avoid an existent shoal area along the eastern side. Through the second reach adjacent to Petit Bois Island the pilots performed an s-turn which is normal practice in this area with the objective of taking advantage of deep water beyond the western channel edge. Through the third and fourth reaches in the Lower Pascagoula Channel the tracklines favor the western side of the channel due to the cross currents and easterly wind. Toward the end of the fourth reach the tracklines become more distributed across the channel. This is a result of the slowing process in preparation for entry into the Bayou Casotte Channel during which time a certain amount of control is lost by the pilot due to lower propeller rotation rates. Generally, in this process the pilots are trying to slow down to a speed of 5 to 6 knots from a speed of 8 to 10 knots. The slowing down is necessary for two reasons: (a) the Bayou Casotte Channel is narrower and the adjacent water depths are shallower causing (when the speed is too high) significant bank suction and shear and (b) many small pleasure craft anchor on the adjacent flats for fishing and other recreation and cannot withstand large ship-wake waves. On the fifth reach the entry into Bayou Casotte invariably caused the ships to slide out of the channel on the western side. This is an indication that LASH ships do not have adequate control in this area and that additional room is needed for this particular maneuver. The remaining portion of the channel is a rather difficult transit for the LASH ship as can be seen on the drawings of the fifth and sixth reaches. The ships are traveling at a low rate of speed and, therefore, control is reduced significantly. It should be noted that normal practice is to use tugs in this portion of the channel to help slow the ship; however, tugs were not used in the simulation tests because the objective was to determine what specific effect channel width has on ship maneuverability in the area. Inclusion of tugs would have confounded the results.

Figure 12 shows the inbound LASH ship runs for the proposed 450/250 channel (scenario #5, Table 2). In this proposed condition the Entrance Channel had a width of 450 ft, the Horn Island Pass Channel was 500 ft wide and the inner channels all had a width of 250 ft. Although in this proposed configuration the shoal along the eastern side of the channel in the first reach no longer existed, the pilots still had a tendency to stick to the western channel edge out of habit. In place of the shoal area was a sediment impoundment basin. Another impoundment basin is proposed along the eastern side of the channel through the area shown on the second reach. In the first two reaches the pilots stayed within the channel alignment; although, the s-turn near the second bend performed during the existing channel runs was again performed by many of the pilots. Good clearances and adequate ship control, to the end of the second bend, are characteristic of the first two reaches on Figure 12. However, the constriction to 250 ft when entering the Lower Pascagoula Channel produced some almost uncontrollable ship behavior.

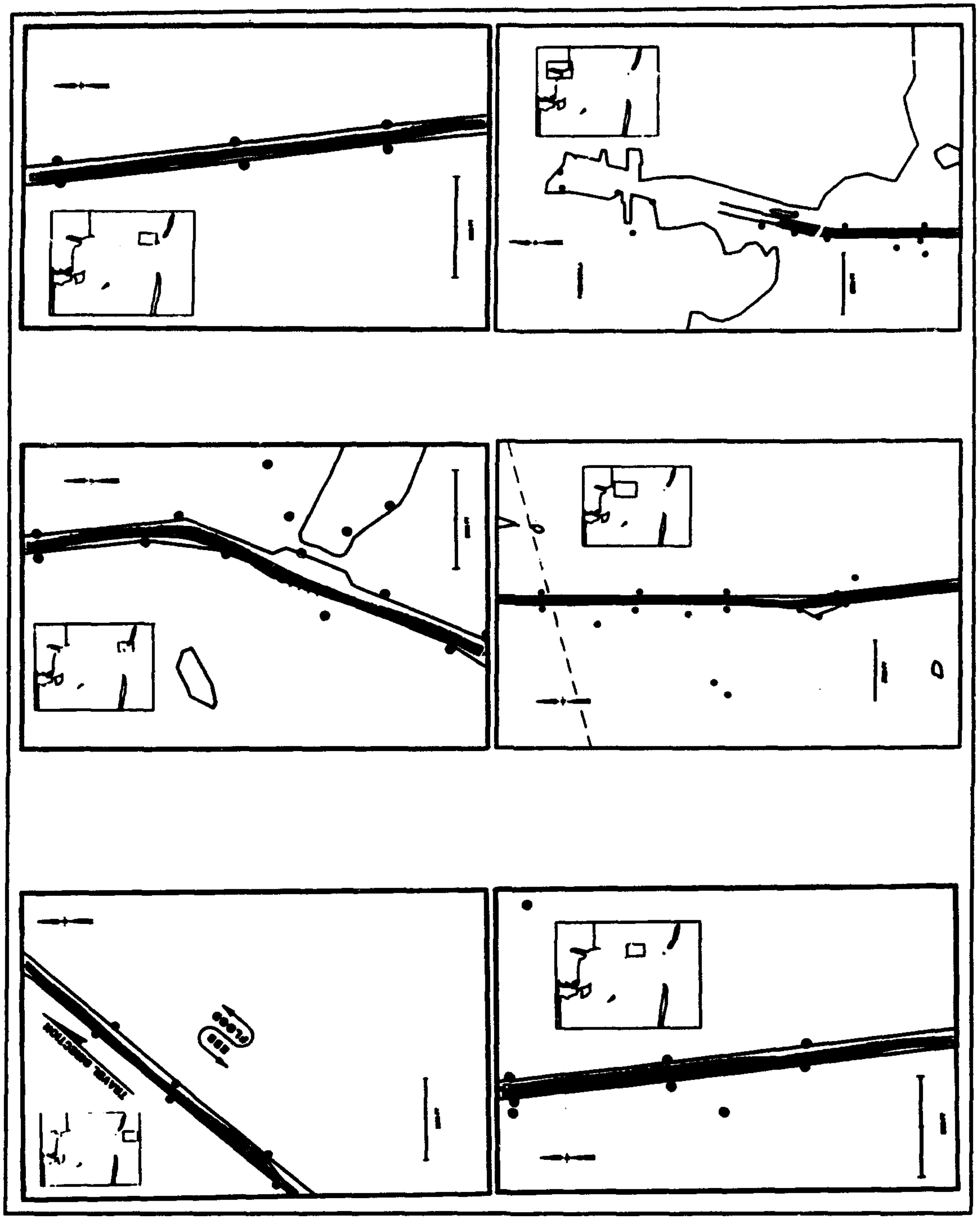

Figure 11. Inbound composite pilot tracklines existing channel, LASH ship (894x100x34), maximum cross current, 15 knot easterly wind

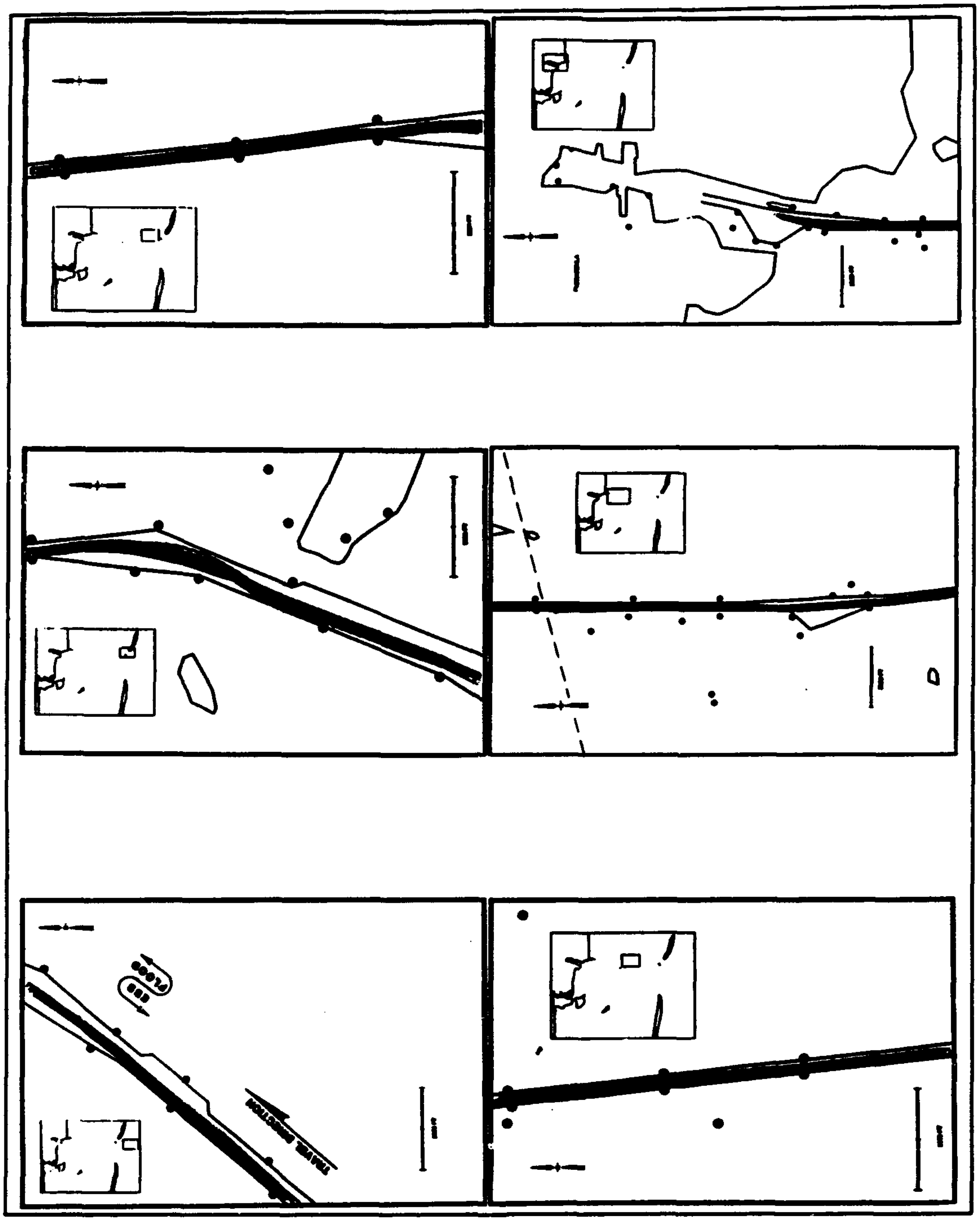

Figure 12. Inbound composite pilot tracklines 450/250 channel, LASH ship (894x100x36), maximum cross current, 15 knot easterly wind

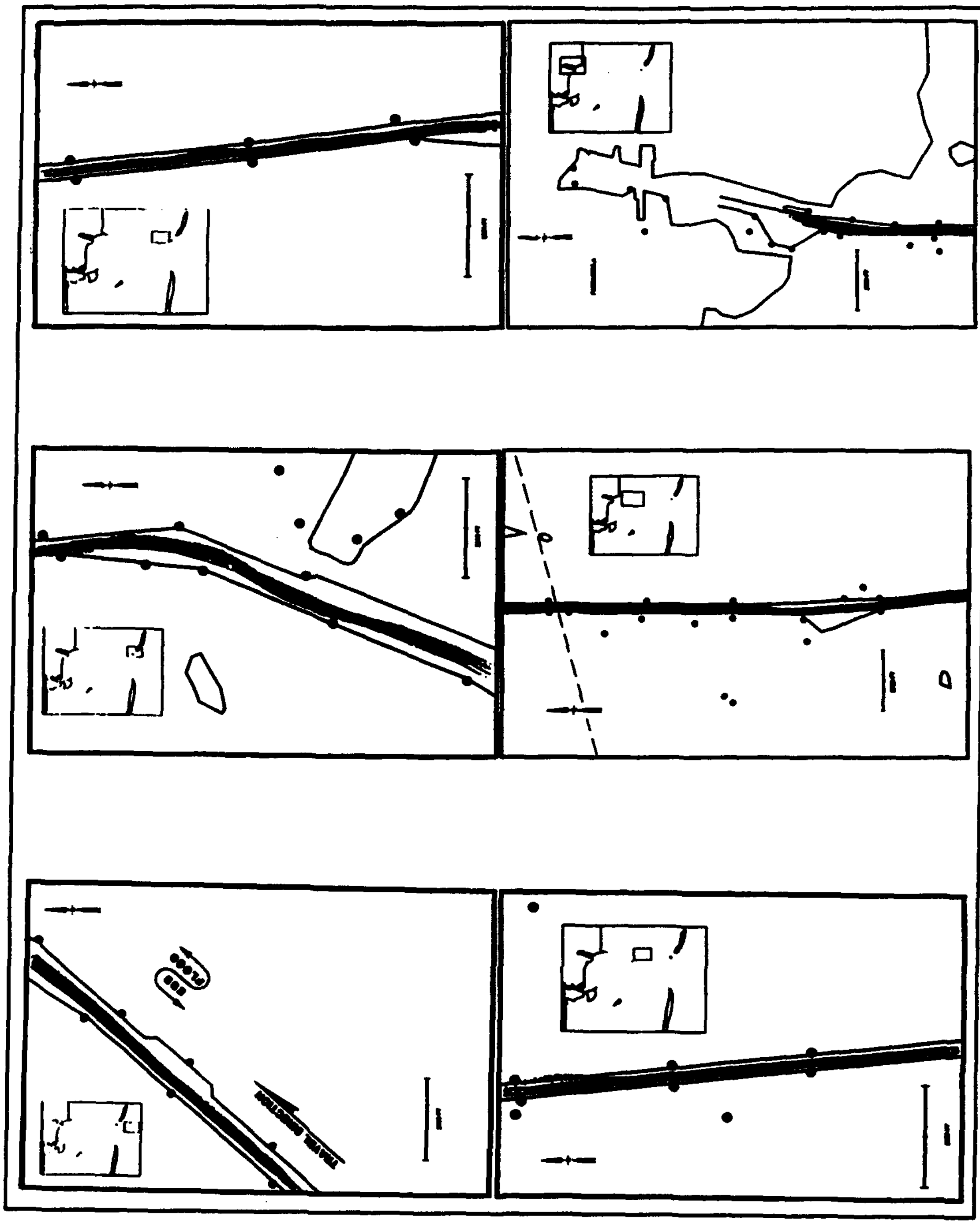

Figure 13. Inbound composite pilot tracklines 550/300 channel, LASH ship (894x100x36), maximum cross current, 15 knot easterly wind

The ship was usually traveling at a high rate of speed around the last bend before arriving at the constriction. The tracklines indicate that the ships made a series of bank shears from side to side before the pilots were able to get them under control. Later, further evidence will be presented showing other indications of these difficulties. Through the remaining portion of the Lower Pascagoula Channel the pilots said much attention had to be paid to keeping the LASH ship under control. In addition, it is evident that clearances to the channel edge are clearly inadequate. Pilot performance at the entrance into Bayou Casotte (the fifth reach) still exhibits a tendency to run out of the channel on the western side. Also, in the fifth reach the composite trackline in the vicinity of the pipeline crossing indicates many channel edge excursions; however, this is not an accurate assessment because only the last two pilots were tested with a asymmetric constriction to 225 ft implemented in the simulator. These last two pilots indicated that they did not consider this constriction likely to cause them problems. The individual tracklines of these pilots in this area also support this contention. The pipeline crossing is at a point in the channel where the ships have finally been slowed down; therefore, not as much channel width is required. In comparison, if the pipeline crossing were farther south closer to the channel junction, it would not be advisable to constrict the channel to such a width. Ship control and clearances in the remaining parts of the Bayou Casotte channel for this set of conditions show no or slight improvement in comparison with the existing channel runs.

Figure 13 shows the results for the LASH ship inbound runs in the 550/300 proposed channel (scenario #6, Table 2). In this scenario the Entrance Channel was 550 ft wide, the Horn Island Pass Channel was 600 ft wide and the inner channels had a width of 300 ft. Clearly, through the first two reaches clearances have improved greatly in comparison to the preceding two channels. The pilots perform the same s-turn off the end of Petit Bois Island but stay well within the channel limits. However, similar to the effect in the 450/250 channel, the sharp constriction to 300 ft at the entrance to the Lower Pascagoula Channel caused the pilots great problems with ship control. In the third reach the clearances are improved over that for the 450/250 channel; however, the tracklines indicate problems with bank shear over the first few thousand feet. Control and clearances seem to be good in the fourth reach with all the pilots' tracklines falling right on top of each other. The trackline which runs out of the channel at the inland end of the fourth reach was a result of a computer failure and that portion of the run can be disregarded. At the entrance to the Bayou Casotte Channel the tracklines indicate same tendency as before in which the ships drift beyond the western channel edge. Through the balance of the Bayou Casotte Channel the clearances clearly are improved with the tracklines within the channel line. The constriction to 250 ft at the pipeline crossing again was tested only for the last two pilots who reported no difficulty.

Figure 14 shows a sampling of results of some of the most significant recorded control measures. The two measures shown are the mean minimum port channel edge clearance and the maneuvering factor. The maneuvering

factor is obtained by multiplying the rudder angle with the propeller rotation rate (in revolutions per minute) at each time step during the simulation. This gives a comparative measure of the amount of ship power being used for maneuvering during the transit. The statistics shown on Figure 8 are the mean value from all five (or more if applicable) pilot runs averaged over each 1000-ft channel section. These sections start at the beginning of the channel definition implemented in the simulator. Changes in channel direction, such as at the intersection of the Pascagoula and Bayou Casotte Harbors, are located on the plots according to the section number.

On Figure 14, the results for the mean minimum port channel edge clearance are shown for the inbound LASH ship runs in all three tested channels. The two sharp dips seen on the plot took place, respectively, at the channel width constriction at the entrance to the Lower Pascagoula Channel and at the main channel bifurcation in the Mississippi Sound. In the existing channel throughout the Lower Pascagoula Channel the clearance fluctuated between 25 and 75 feet. In the Bayou Casotte Channel the port clearance remained negative (outside the channel edge) for the entire reach. In the 450/250 channel the minimum port clearance in the Lower Pascagoula Channel averaged approximately 25 ft while in the Bayou Casotte a slight improvement can be seen in comparison to the existing 225-ft wide channel. In the 550/300 channel the minimum port clearance in the Lower Pascagoula Channel shows improvement over the 450/250 channel averaging between 50 and 75 ft while the clearance in the Bayou Casotte Channel fluctuated around 50 ft. Because it is normal practice for tugs to be in use in the Bayou Casotte Channel, 50 ft clearance is probably adequate. In the Lower Pascagoula Channel, however, 50 to 75 ft is a marginal clearance value when considering the range of conditions possible in the area. It should also be noted that negative minimum clearances were recorded at the entrance to the Bayou Casotte for all three channels indicating a need for additional maneuvering room.

Figure 14 also shows the mean maneuvering factor depicted in the same fashion as the clearances. The extreme dip and peak for all three channel configurations happens near the second bend at the end of the Horn Island Pass Channel. The maneuver around this bend was evidently more difficult in the proposed channels than in the 350-ft wide existing channel as shown by the somewhat higher mean value of the maneuvering factor. One of the most noticeable results obtained is the fluctuations in the maneuvering factor after the ships enter the Lower Pascagoula Channel which is constricted in the proposed channels. These fluctuations seem to damp out faster in the existing channel than in the proposed channels. The cause of these fluctuations is the rudder swinging back and forth while the pilot tries to control strong bank shear resulting from the high speed at which the ships are traveling when making the entrance. Several thousands of feet are required before good control is again obtained. This point is located in the area where the maneuvering factor settles down to a relatively steady value throughout the remaining portion of the Lower Pascagoula Channel.

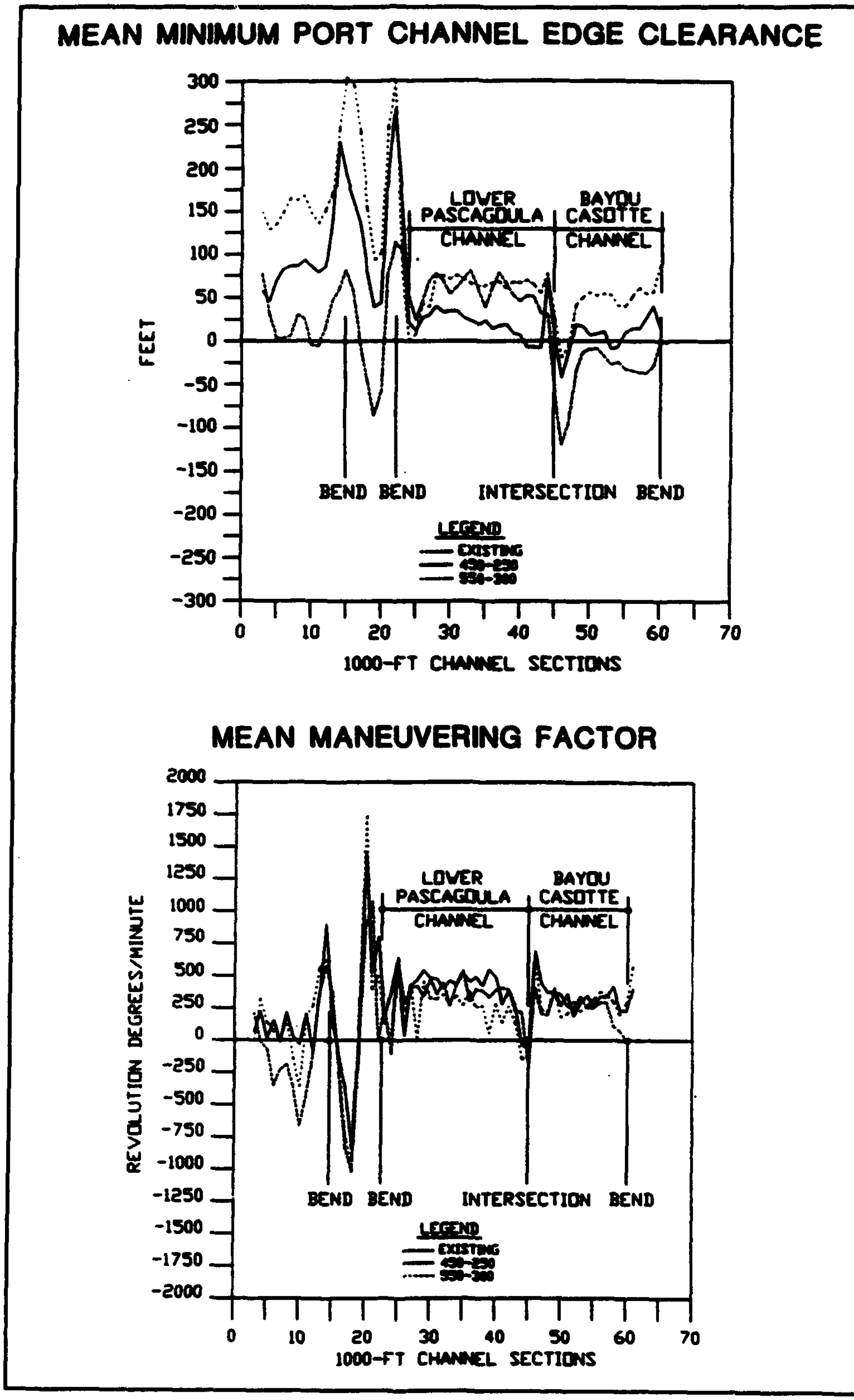

Figure 14. Inbound LASH ship control measure statistics

In this region the 450/250 channel shows a fairly high level of positive maneuvering factor (positive rudder angle rotates the ship counter-clockwise) while the existing channel and the 550/300 channel show a somewhat lower level of ship power.The next big jump in ship power activity is at the entrance into the Bayou Casotte Channel with a subsequent settling down for the remainder of the run.

Tanker runs

Figures 15-17 show the composite tracklines for the inbound tanker runs conducted with maximum ebb tide and 15 knot easterly wind. Based on these tracklines, in general this particular tanker seems to handle better than the LASH ship, probably due to its larger size and slower speed. However, in the 450/250 channel (scenario #2, Table 2) in the Lower Pascagoula Channel the tracklines take up most of the channel width with a significant amount of side-to-side maneuvering (as seen before with the LASH ship). Also, it is interesting to note that the pilots ran out of the western side of the channel at the entrance to Bayou Casotte in the existing channel (scenario #1, Table 2) but did not in the proposed channels (scenarios #2 and #3, Table 2).
Figure 18 shows the plotted results of the mean minimum port channel edge clearance for the three channels. For the existing channel the results are generally negative in the Bayou Casotte Channel whereas for the proposed channels positive clearances are noted in the same area. The 300-ft width in this area allows the minimum port clearance to be generally around 50 ft.

Bulk carrier runs

Figures 19-24 show the composite tracklines for the inbound and outbound pilot runs conducted with a loaded bulk carrier. These particular ships frequent the Pascagoula branch of the study channel. Generally, the tracklines show, and the pilots agreed during testing (see section on pilot ratings), that the bulk carriers in the simulation were not difficult to handle, even in the narrow 250-ft wide channel. This is an indication that the most critical set of conditions was probably not tested in this reach of the channel. One possible explanation is that the ships tested were very heavy, sluggish vessels and, consequently, ship speed was not high enough to cause significant bank suction. Possibly a shorter, faster ship with a comparable draft would be a more critical vessel. Based on this reasoning and without further information concerning this reach it would be inadvisable to recommend channel narrowing, especially in consideration of the test results from the Lower Pascagoula Channel discussed earlier. In any event, there is one critical area in the channel for which the recorded simulator runs are definitive. This area is the intersection of the Pascagoula and Bayou Casotte Channels where, during the inbound runs shown on Figures 19-21, the tendency was for the vessels to drift beyond the channel edge on the northern side while negotiating the turn into the Pascagoula Channel. These results from all three tested channels indicate that additional widening over and above a width of 350 ft is needed for a short portion of the channel on this side.

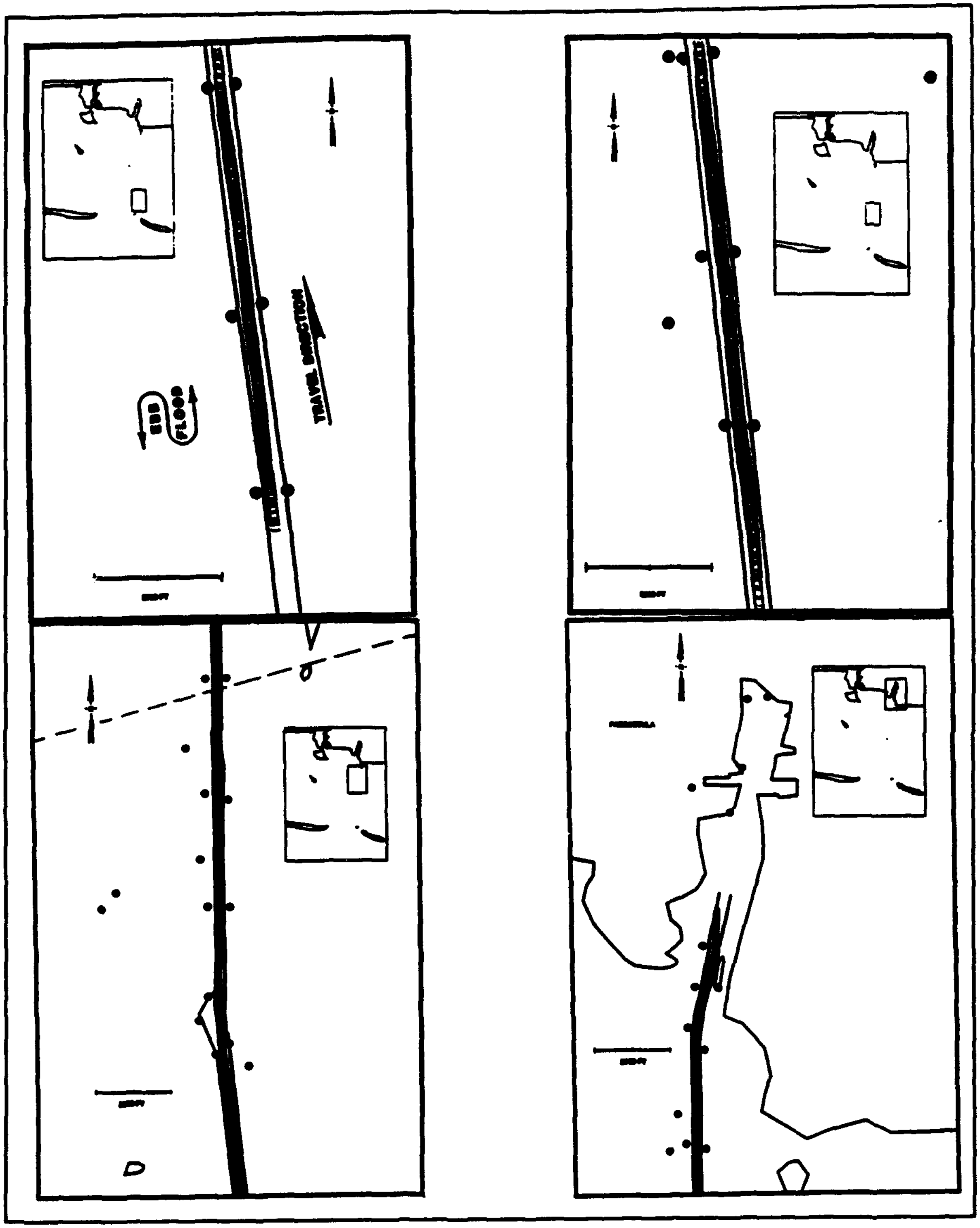

Figure 15. Inbound composite pilot tracklines existing channel, tanker (810x125x36), maximum ebbing current, 15 knot easterly wind

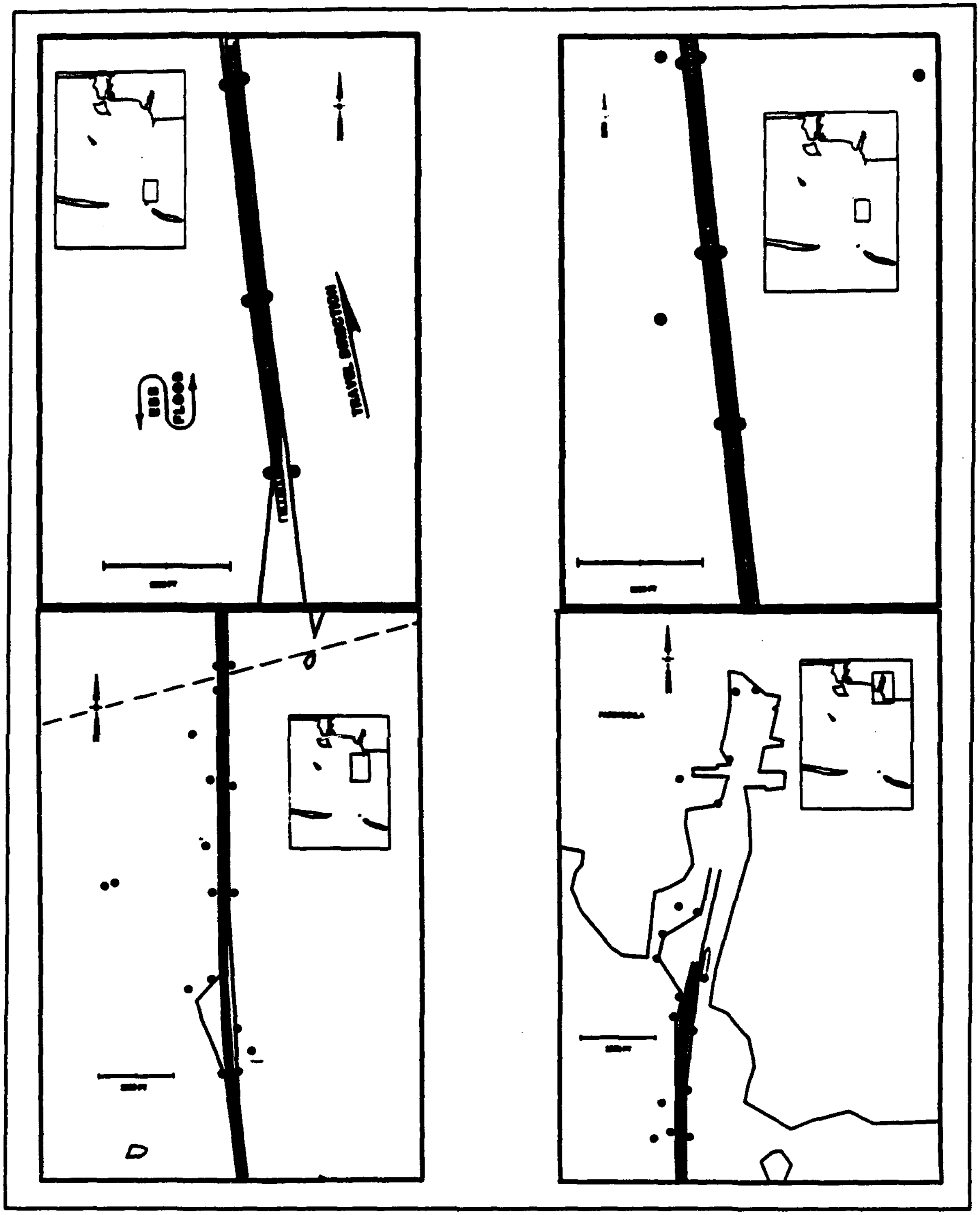

Figure 16. Inbound composite pilot tracklines 450/250 channel, tanker (810x125x40), maximum ebbing current, 15 knot easterly wind

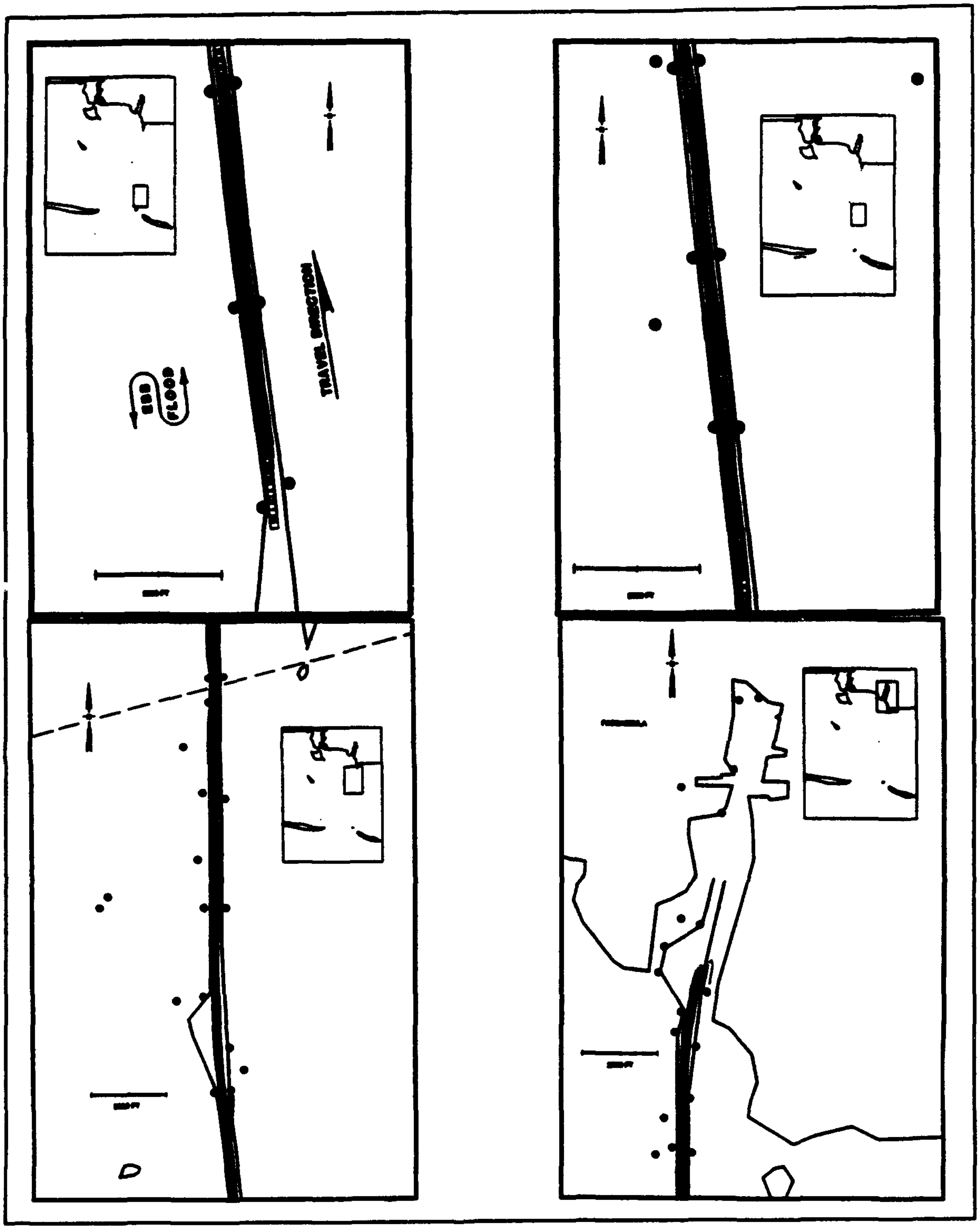

Figure 17. Inbound composite pilot tracklines 550/300 channel, tanker (810x125x40), maximum ebbing current, 15 knot easterly wind

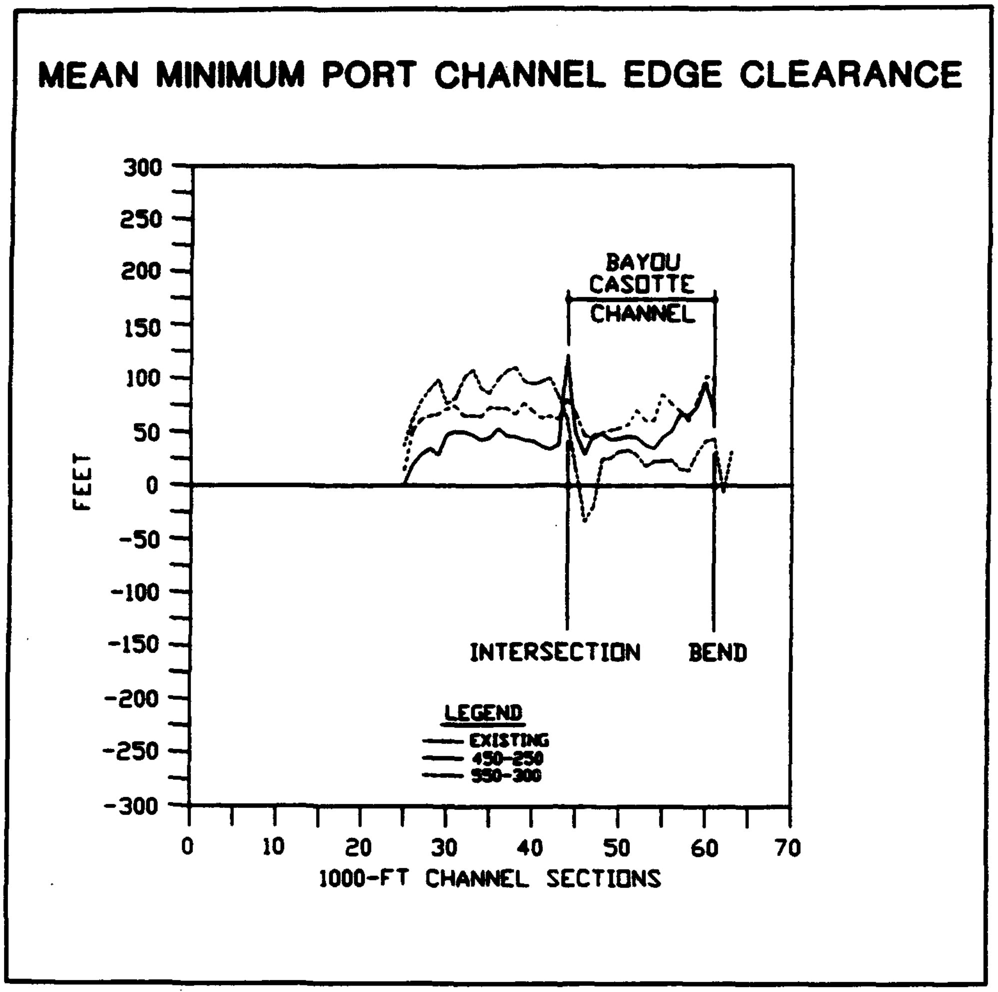

Figure 18. Inbound tanker control measure statistics

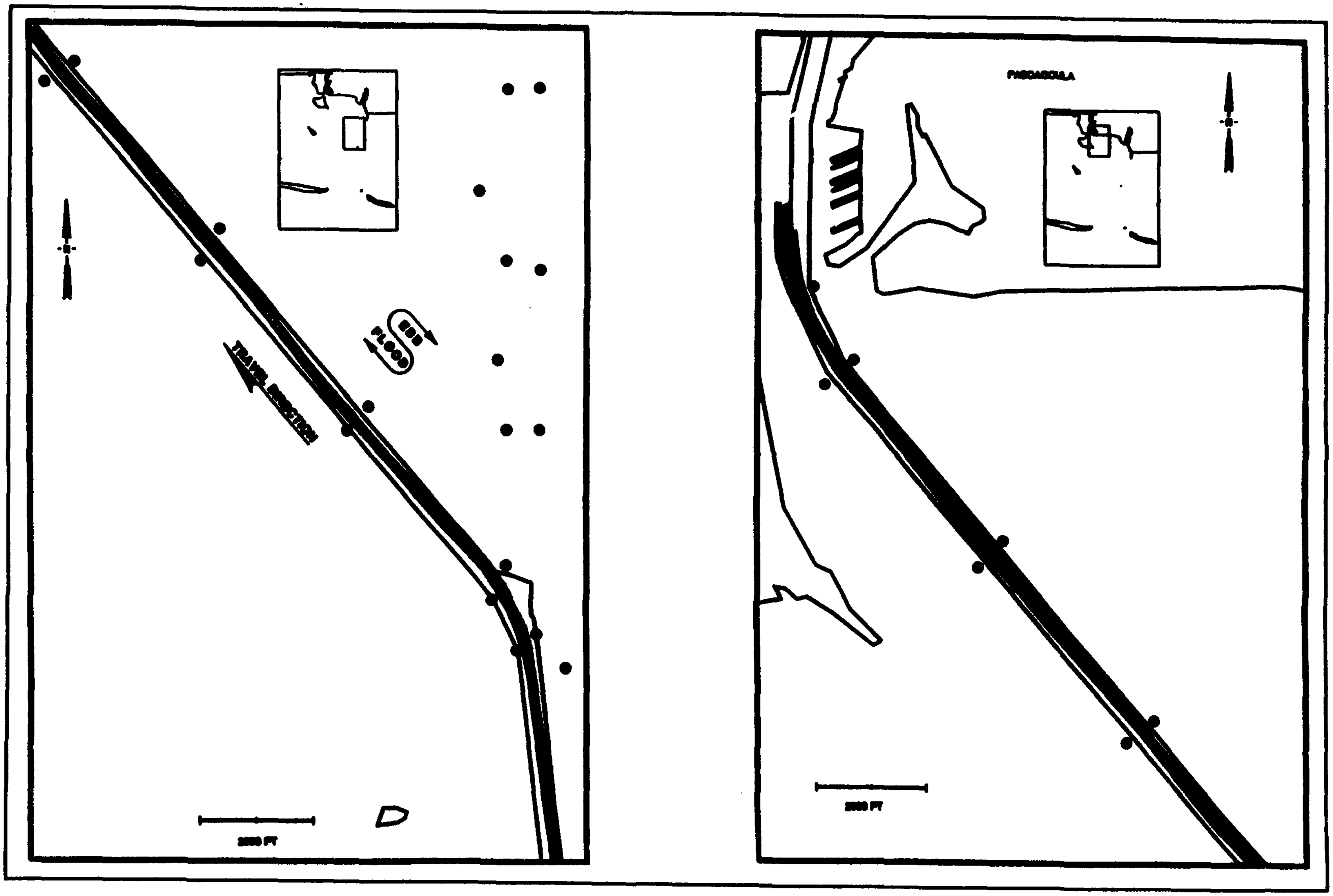

Figure 19. Inbound composite pilot tracklines existing channel, bulk carrier (775x106x36), maximum ebbing current, no wind

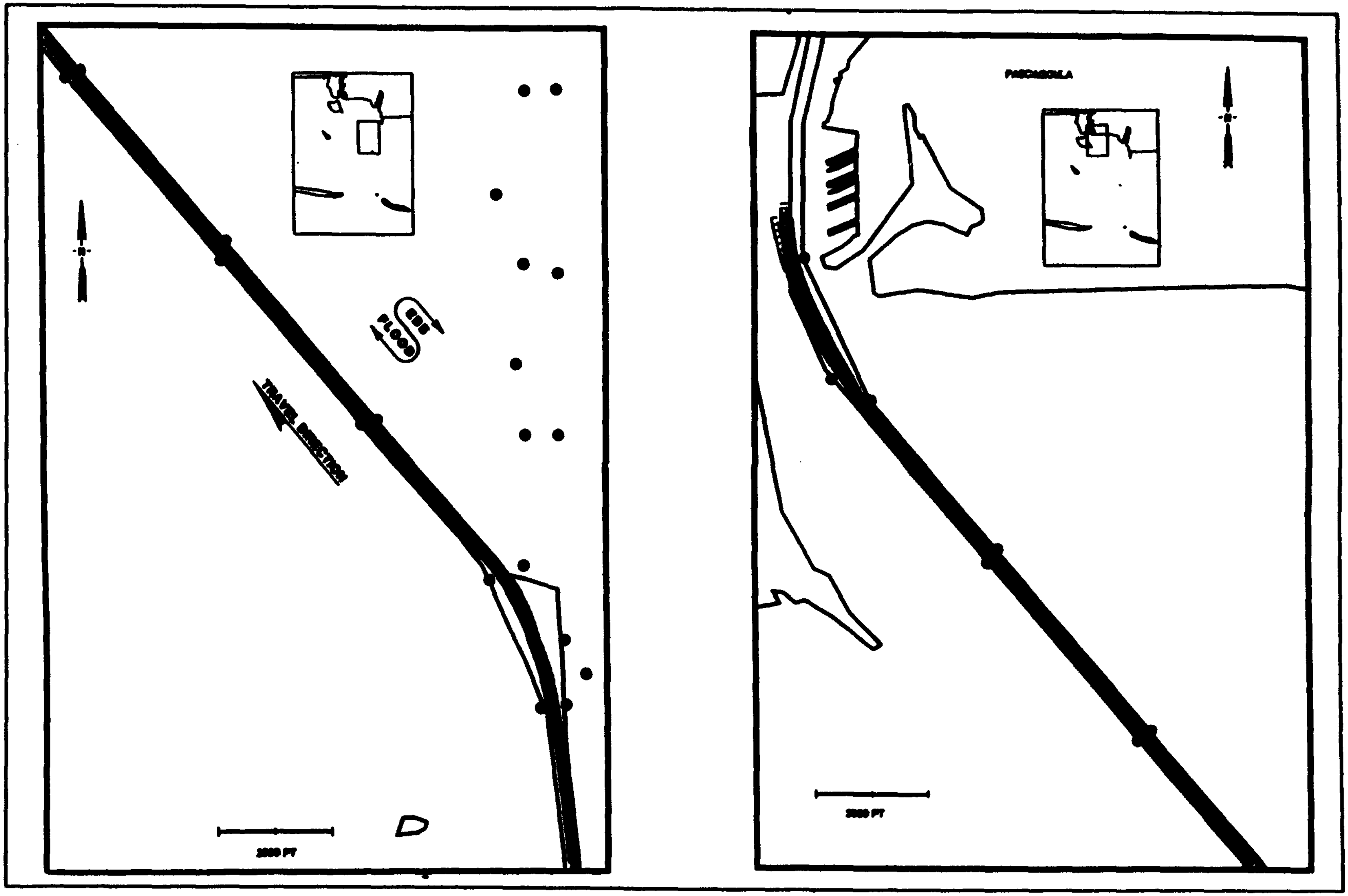

Figure 20. Inbound composite pilot tracklines 450/250 channel, bulk carrier (850x106x40), maximum ebbing current, no wind

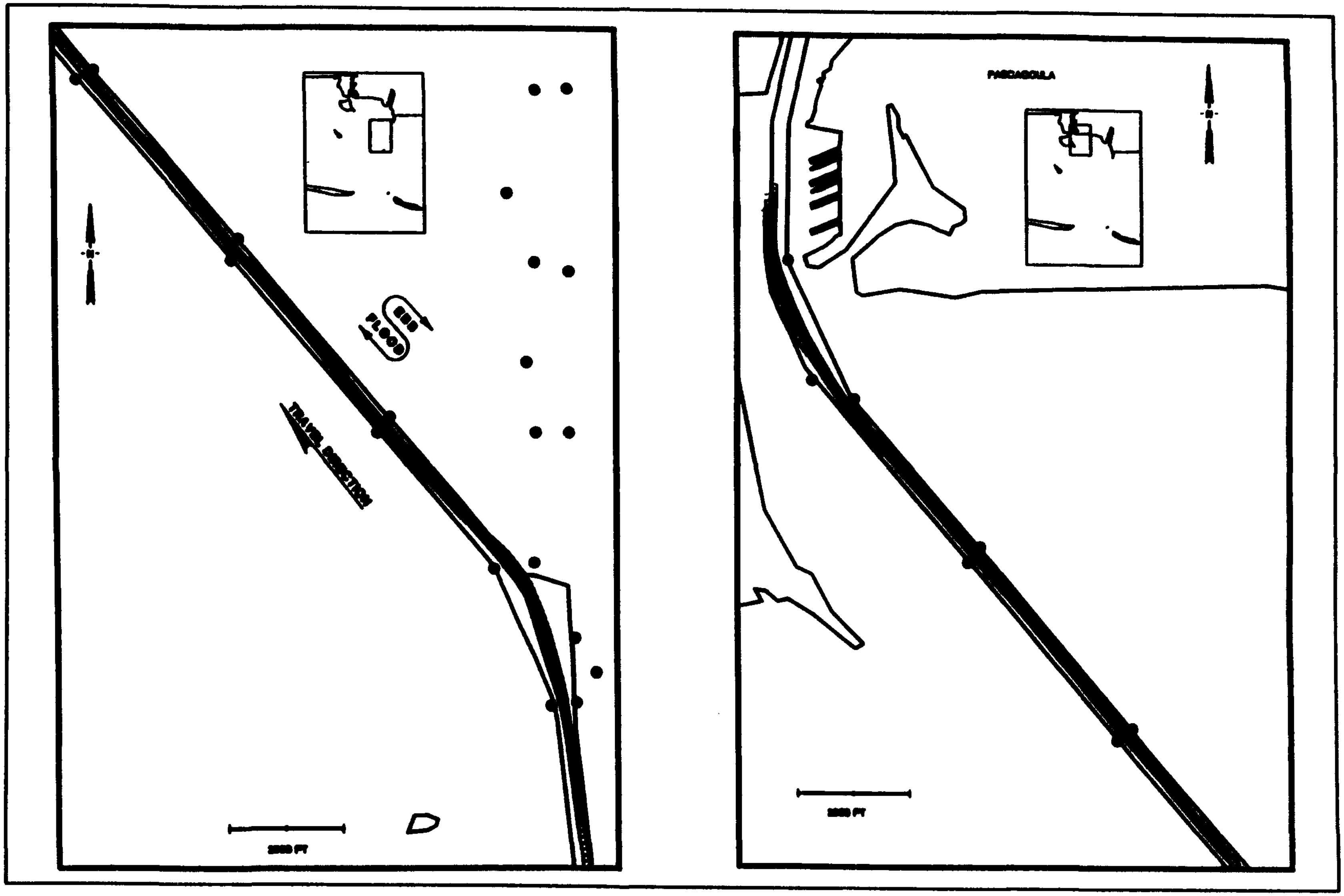

Figure 21. Inbound composite pilot tracklines 550/300 channel, bulk carrier (850x106x40), maximum ebbing current, no wind

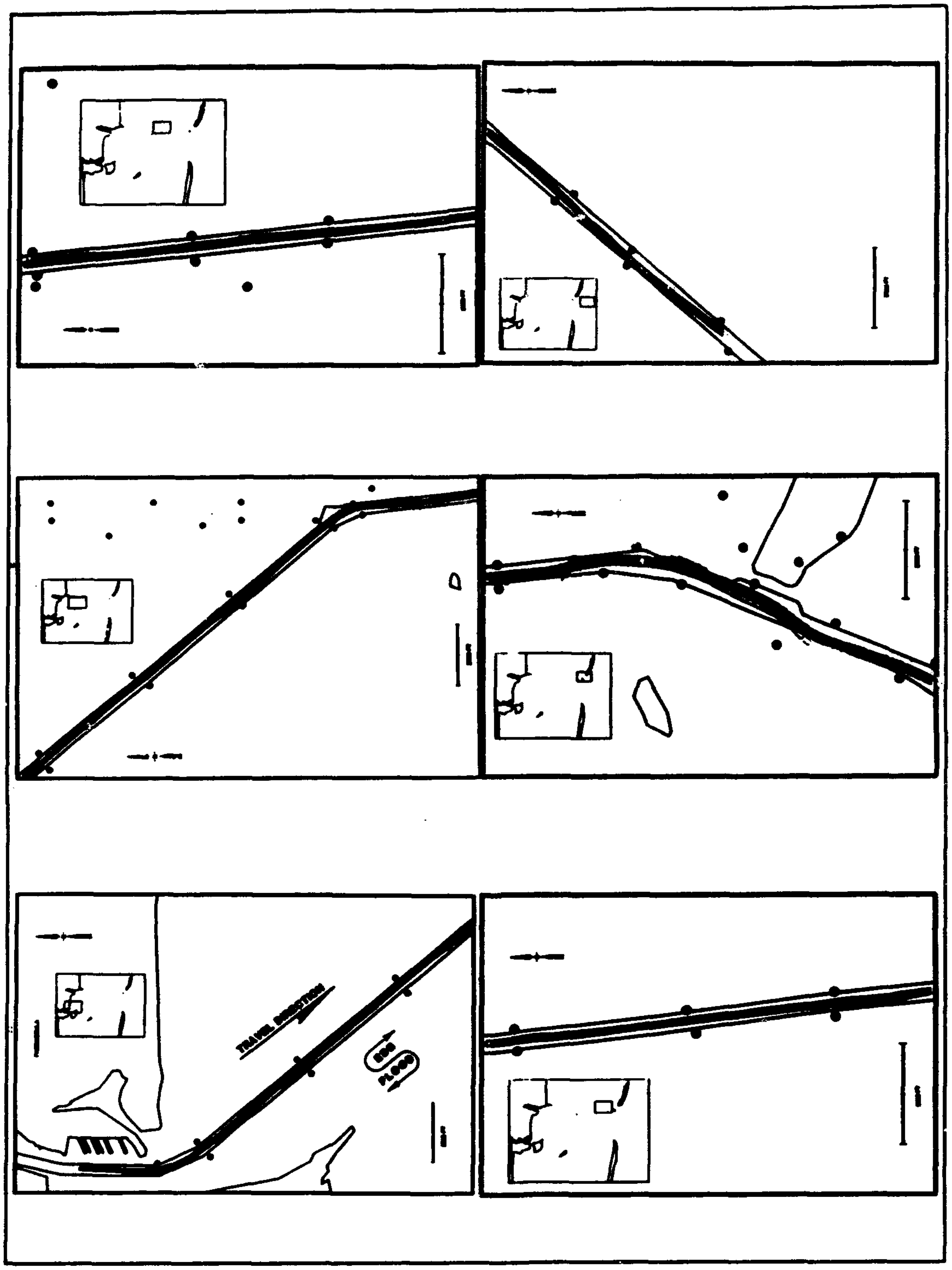

Figure 22. Outbound composite pilot tracklines existing channel, bulk carrier (775x106x36), maximum flooding current, no wind

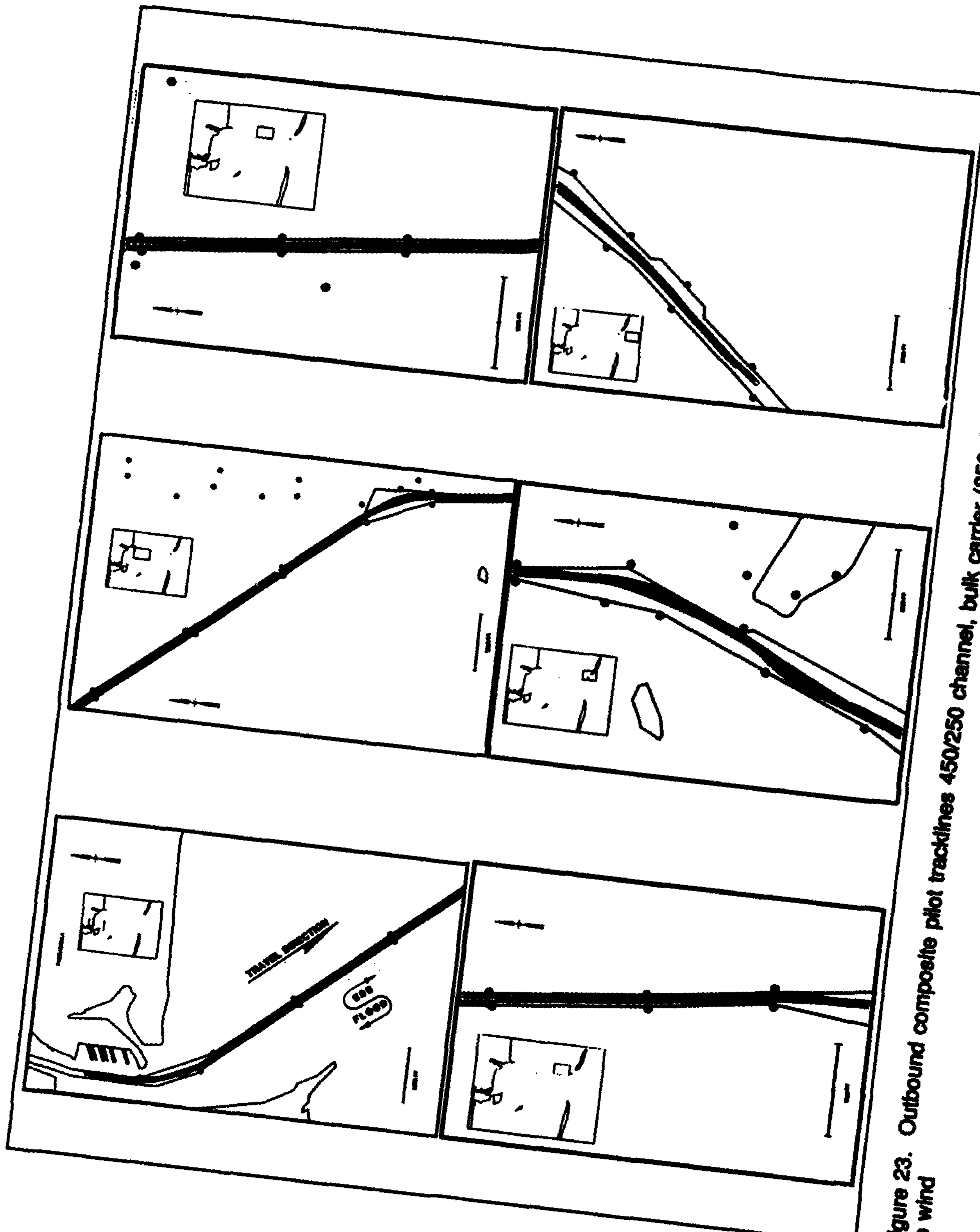

Figure 23. Outbound composite pilot tracklines 450/250 channel, bulk carrier (850x106x40), maximum flooding current, no wind

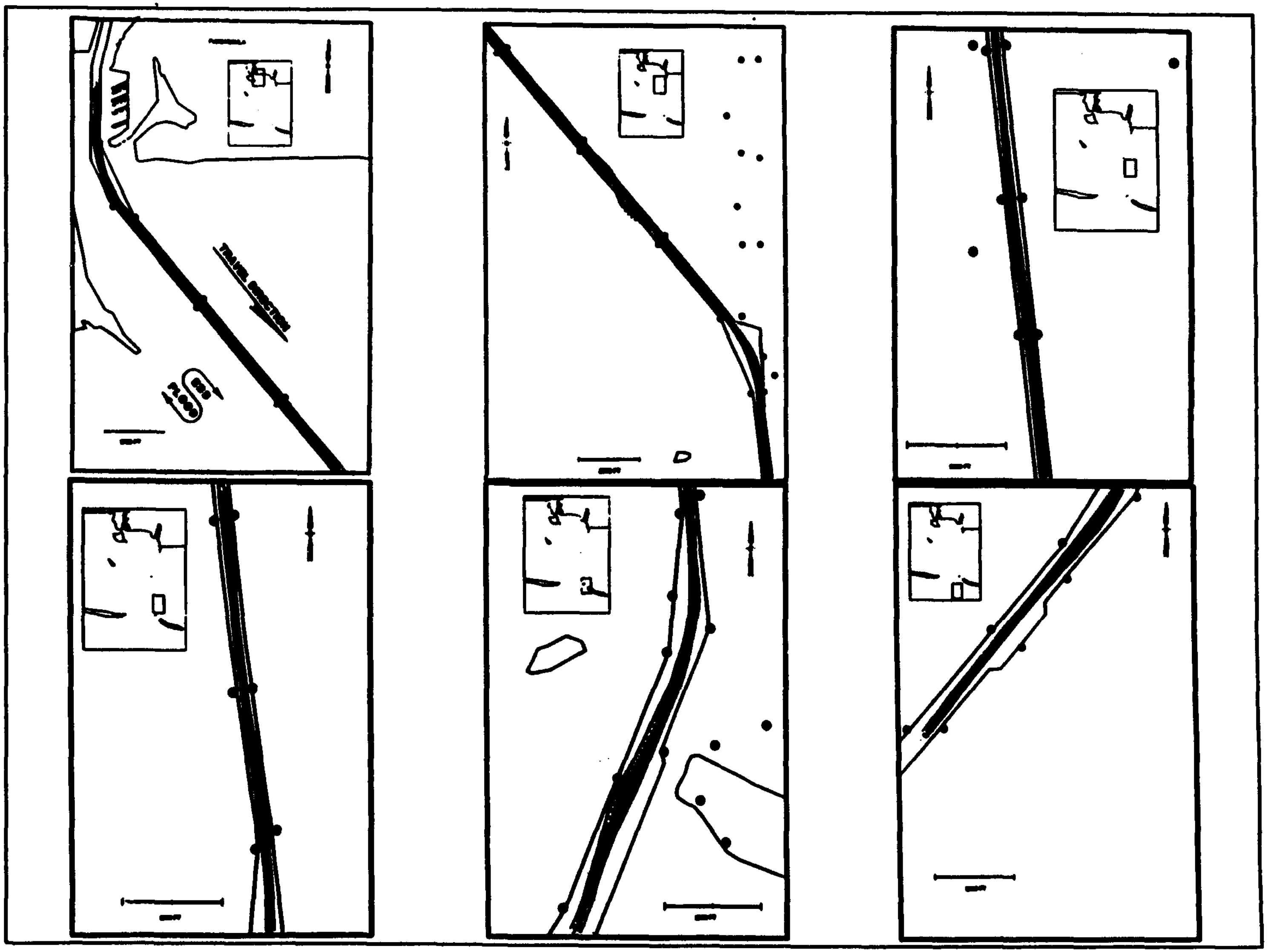

Figure 24. Outbound composite pilot tracklines 550/300 channel, bulk carrier (850x106x40), maximum flooding current, no wind

Pilot Questionnaire Response Analysis

In order to document the visiting pilots' own thoughts concerning the simulation study and the channel design project in general, two different types of questionnaires were given. After each simulation a test questionnaire was handed to the pilot for him to rate the run just completed for difficulty and realism. At the end of each visit a final debriefing questionnaire was given to allow the pilot to express his ideas and opinions of the channel project and simulator in general. In Appendix A, examples of these two questionnaires are included. In the following analysis the reader is cautioned that pilot ratings must be considered with a reasonable amount of caution; however, they can, with careful interpretation, be a general comparative measure of the different test scenarios.

The primary problem with analyzing questionnaire ratings is that each pilot has his own personal idea of what is easy or difficult and real or unreal. Consequently, the raw results from questionnaire ratings on the 0 to 10 scale frequently possess a large amount of scatter between pilots. For example, one pilot may rate all the questions concerned with realism or accuracy versus unrealism or inaccuracy in a 7 to 10 range while another may choose ratings in a 2 to 9 range. In a comparative study information is lost during the process of averaging these raw scores. Considering the pilot ratings, x, as normal random variables, they can be normalized using the individual pilots' sample mean rating, $\bar{x}$, and his sample rating standard deviation, s. To accomplish this, all ratings chosen by each individual pilot on the scale of "very unrealistic" to "very realistic" and "very inaccurate" to "very accurate," were algebraically added and analyzed for the sample mean and standard deviation. The same process was carried out for the questions involving "very easy" to "very difficult" and "very simple" to "very difficult." New standardized random variables were then calculated for channel scenario comparison according to the following normal random variable relation,

$$X = \frac{x - \bar{x}}{s}$$

in which X are the standardized ratings of a particular pilot with mean of 0 and standard deviation of 1. The following tabulation presents the results of this analysis for the most critical pilot rating questions. For the ratings presented above, the higher the number the greater was the perceived difficulty and accuracy. The bulk carrier runs were rated the easiest and generally the least accurate as far as ship behavior is concerned. The smaller bulk carrier in the existing channel, *El Gaucho*, was rated as significantly more accurate in behavior than the proposed channel ship, *Delaware*. The ship behavior ratings for scenarios 4, 5 and 6 (LASH ship inbound) indicate less accuracy for the existing channel than for the proposed scenarios.

Scenario # from Table 2	Overall Difficulty of Run	Accuracy of Ship Behavior
1 (existing)	.4	.3
2 (450/250)	.5	.3
3 (550/300)	.2	.2
4 (existing)	.1	-.1
5 (450/250)	.4	.6
6 (550/300)	.2	.5
7 (existing)	-.5	.6
8 (450/250)	-.1	-.4
9 (550/300)	-.2	-.7
10 (existing)	.0	.6
11 (450/250)	.3	.1
12 (550/300)	.2	.7
13 (turning basin)	-.4	1.0

There is no recognizable explanation for this other than perhaps the pilots rated the existing channel more critically for this ship because of having first hand knowledge of existing conditions. Without exception the 450/250 channel was rated as more difficult than the existing channel. Out of the first three scenarios the 550/300 channel was rated easier than the existing channel probably because the Bayou Casotte Channel was significantly wider than in the existing case. For the remaining scenarios both proposed channels were rated as more difficult than the existing channel. The turning basin scenario was rated as fairly easy. The following section deals with the pilot ratings for ship controllability for each of the channel segments, separately. It is suggested that the ship controllability can be interpreted in the same way as difficulty. For these numbers, the more positive the rating value the greater the difficulty of controlling the ship. Ratings for this question were not obtained for the Bayou Casotte Turning Basin. For the Entrance Channel the proposed wider channels were rated as easier than the existing without exception; however, the 550 ft wide channel was rated as more slightly more difficult than the 450 ft channel. For the Horn Island Pass, no significant difference was rated between the channels for the LASH ships, but for the outbound bulk carriers the proposed channels were scored as much easier; although, again, the widest channel (600 ft) was rated more difficult than the next widest (500 ft) channel.

Ship Controllability					
Scenario #	Entrance Channel	Horn Island Pass	Lower Pascagoula Channel	Upper Pascagoula Channel	Bayou Casotte
1 (existing)	—	—	.2	—	.6
2 (450/250)	—	—	.4	—	.6
3 (550/300)	—	—	.1	—	.6
4 (existing)	-.3	-.5	-.2	—	.8
5 (450/250)	-1.0	-.4	1.2	—	.5
6 (550/300)	-.8	-.4	.9	—	.4
7 (existing)	—	—	—	-.2	—
8 (450/250)	—	—	—	.0	—
9 (550/300)	—	—	—	-.3	—
10 (existing)	-.1	.6	-.3	-.6	—
11 (450/250)	-.8	-.6	.3	.6	—
12 (550/300)	-.4	-.2	-.2	.0	—

These unexpected results are partially due to one pilot rating scenario #12 very difficult for unexplained reasons. If this particular pilot's ratings are disregarded the 550/300 channel is rated easier than the 450/250 channel for that particular scenario. On the other hand, it appears that on average the pilots could discern little difference between the proposed channels during the LASH ship runs (scenarios 5 and 6) through these two channel reaches. These results tend to support the findings in the next section in which the narrower of the two proposed channels is recommended. The reader is reminded at this point about the later section on the additional entrance area simulation testing, which further discusses these same reaches. Continuing the discussion with the Lower Pascagoula Channel, the pilots rated the proposed channels more difficult than the existing case for the LASH ships, but less significant differences are seen in this reach for the tanker and bulk carrier runs. For the Upper Pascagoula Channel the outbound bulk carrier runs were rated more difficult in the proposed channels and for the inbound runs little difference can be seen between the channels. For the Bayou Casotte Channel the LASH ship runs were rated significantly easier in the proposed wider channels, but for the tanker runs the pilots reported no difference. The ratings results tend to support the final recommendations by suggesting that the narrowest proposed width in the entrance area is acceptable and the widest proposed width in the interior channels is necessary.

Final Debriefing Questionnaire

In general, the final opinions of the pilots suggested that the widest possible width be constructed for all the channel segments. This is especially true for the Entrance Channel and Horn Island Pass where most of the pilots' concerns centered. All the pilot responses spoke of the need to test worse conditions in the entrance area because of wind, waves, currents and difficult handling ships. These responses were part of the impetus for the additional tests for the entrance area. On another matter, the pilots seem to regard the proposed turning basin as acceptable with the exception of one who thought a square basin would be better. Appendix A presents in their entirety the pilot responses to each of the questions.

4 Recommendations on Initial Simulation Tests

Figures 25 and 26 show the channel design recommendations resulting from the initial simulations. For brevity, the straight channel reaches are not shown on these figures. Nominally, the recommendations are as follows: (a) 450-ft channel width in the Entrance and Horn Island Pass Channels, (b) 350-ft width for the entire Pascagoula Channel and (c) 300-ft width in the Bayou Casotte Channel with a constriction to 250 ft at the pipeline crossing. Furthermore, additional widenings are recommended at the southern entrance to the Lower Pascagoula Channel and in two places near the intersection of the two channel branches. The alignment on the western side at the southern entrance to the Lower Pascagoula Channel is recommended for a more gradual transition from the relatively wide Horn Island Pass into the 350-ft width in the Pascagoula Channel. This gradual transition to the narrower width should provide the pilots relief from an immediate increase in bank forces while slowing down brought on by a quick contraction. Alignment of the proposed turning Basin in the Bayou Casotte harbor is recommended as shown in Figure 26 and as discussed earlier. The 1150-ft width in the turning basin should be adequate. It is also recommended that the bends leading into the Pascagoula and Bayou Casotte Harbors be constructed as proposed. The recommendation of a width of 450 ft in the Entrance and Horn Island Pass Channels was based on testing a fairly difficult set of channel conditions (easterly wind and cross-current); nevertheless, adequate clearance and acceptable levels of control (rudder activity, clearances, etc.) were recorded during the pilot runs. However, the pilots expressed a strong desire for the bar channel to be greater than 450 ft due to strong and unpredictable wind and tidal currents and for transiting the channel at night. In the following sections the additional entrance area simulations are discussed during which this area was reexamined.

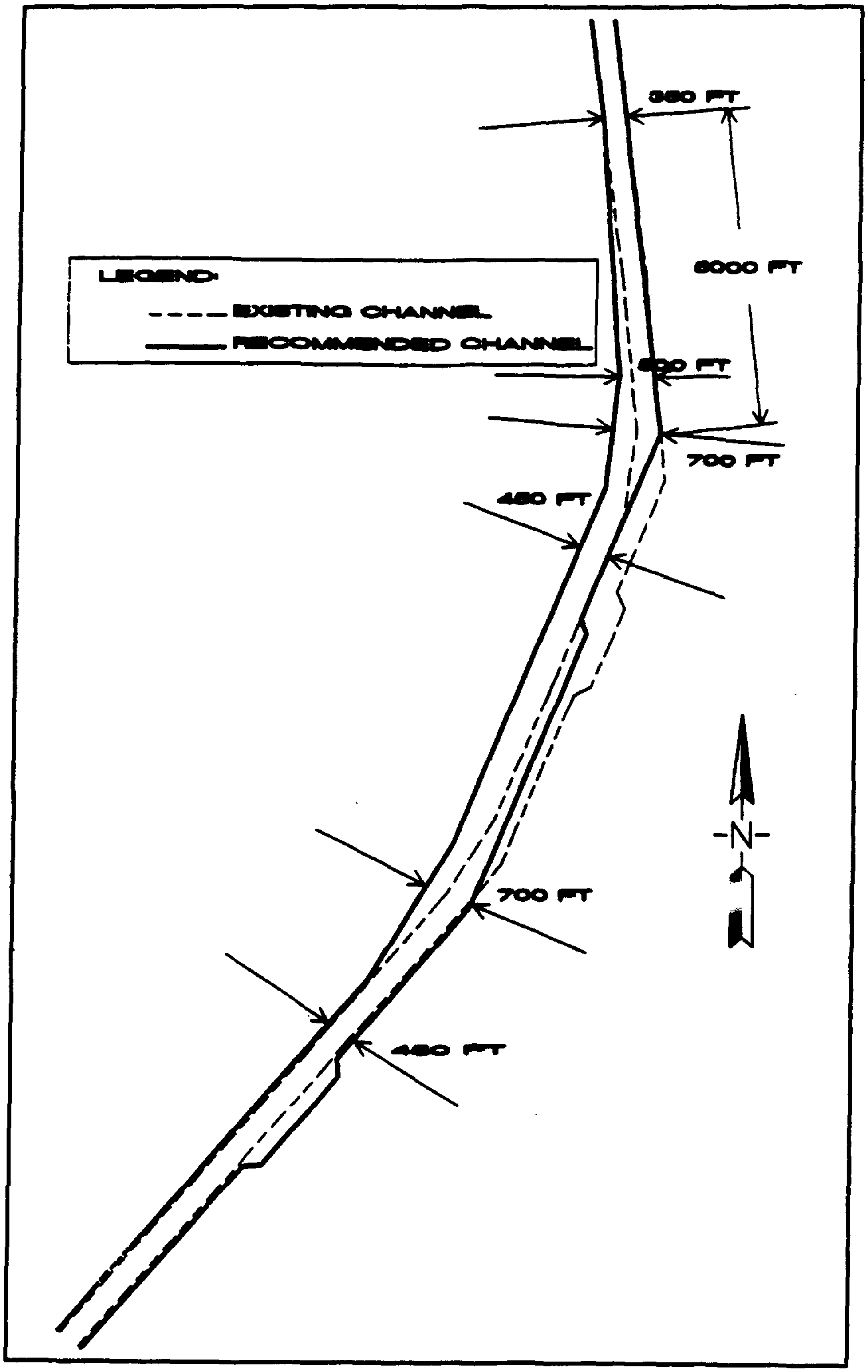

Figure 25. Recommended alignment for Entrance and Horn Island Pass Channels based on initial simulation tests

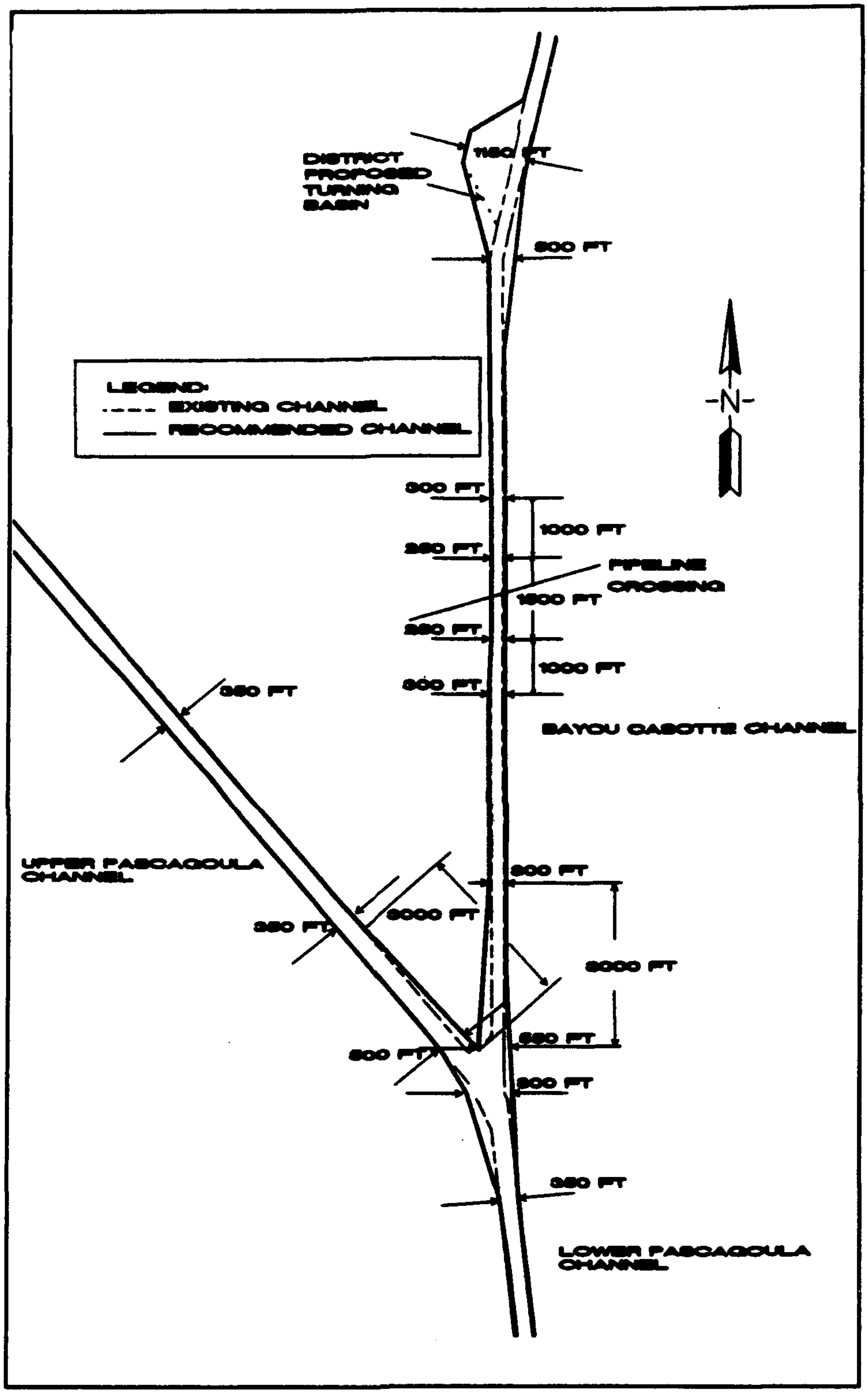

Figure 26. Recommended alignment for a portion of the Pascagoula and Bayou Casotte Channels

5 Additional Entrance Area Simulations

Additional simulator tests were scheduled after the Pascagoula pilots expressed concern about the recommendations from the initial simulations. The pilots' primary concern in the entrance area was (and is) one of vessel control in the Entrance Channel and through the Horn Island Pass. Specifically, nighttime transits are considered the most critical and, with the 350-ft existing channel width and significant shoaling problems, the new class of lightering tankers (see section on ship model data development) are limited by the pilots to daytime transits. The purpose of the additional simulator tests was to focus on the entrance for a more refined recommendation on the required channel width.

Test Conditions for Entrance Area Simulations

For these tests a numerical ship model was developed for the new lightering tankers and was used by the pilots in daytime and nighttime conditions in existing as well as three different proposed channel width configurations. These new lightering tankers are 784 ft long and 122 ft wide with a design draft of 36 ft and are possibly the largest ships in the world equipped with the recently developed Schilling rudder. These rudders are specially designed to allow up to 70 degrees of deflection, which at low speeds allows them to be used essentially as stern thrusters. The exact design of these rudders is proprietary information; however, the enhanced effectiveness of them is partially due to the large deflection angles possible and partially due to end plates (and other undisclosed features) which prohibit boundary layer separation in the lee of the rudder and results in an redirection of the propeller wash producing added lateral force (Ankudinov 1989). During the simulations runs were performed with a LASH ship as well as the tanker in an effort to cover a wide range of navigation conditions for the harbor entrance area. Two professional pilots from the Pascagoula Pilots Association participated in the tests for the Entrance Channel and Horn Island Pass. In addition, Chevron, Inc., the owner and operator of the new class of lightering tankers in Pascagoula, sent a shipmaster to participate in the tests. This particular shipmaster did not have extensive experience in transits through the Pascagoula

channels; however, he did have related experience with petroleum tankers in other harbors. The Pascagoula pilots conducted tests with the LASH ships; however, the Chevron shipmaster did not because of lack of experience on this type of vessel.

Four different channel configurations were tested: one existing and three proposed. Figure 27 presents comparisons of the three proposed conditions with the existing channel alignment. The 450/250, 550/300, and recommended (450/350) channels are the same configurations as for the initial simulation tests. Since the lightering tankers are in ballast loading condition when outbound, only inbound transits were tested. The transits started at the channel entrance and ended after the second bend near Petit Bois Island. The drafts of the ships were the same as for the earlier tests. The two pilots conducted runs in each channel alignment during simulated daytime and nighttime conditions with both the LASH ship and tanker. Therefore, 16 runs were completed by each of the two pilots. The shipmaster conducted eight runs with the tanker only.

Other test conditions included a 25-knot easterly wind imposed during the LASH ship tests. No wind was included in the tanker tests. In addition, maximum spring ebb tide through Horn Island Pass was tested instead of the crosscurrent condition used during the first set of simulator tests. This condition was from the same tidal cycle but at a different hour. Refer to Figure 5 for a picture of the currents in the simulated test channel. This figure depicts the currents for the existing channel scenario. Similar current patterns were used in the simulations for the three proposed channel scenarios. The vectors are difficult to discern in the ocean entrance because they are directly perpendicular to the channel alignment. Maximum depth-averaged current velocity in the vicinity of Petit Bois Isl' ' is on the order of 2.0 knots. However, more important than the cu... velocity in this area is the current direction which is strongly influenced by the proximity of the island. It should be noted that these channel currents are more critical for the Horn Island Pass than those used during the initial simulations.

One of the primary purposes of the additional simulations was to test nighttime conditions. To simulate darkness, the amount of information presented to the pilots on the simulator was reduced to a minimal level. During daytime tests, the pilots had the visual scene as well as the simulated radar screen for guidance. During nighttime tests, the room was darkened and the radar screen was turned off allowing the pilots to see only the flashing navigation lights in the visual scene. This was done as a practical way to deny the pilots the same amount of information as was available during daytime runs, thus creating the most difficult visual condition. During either time of day, the pilot had access to digital navigation data such as heading and ship's speed.

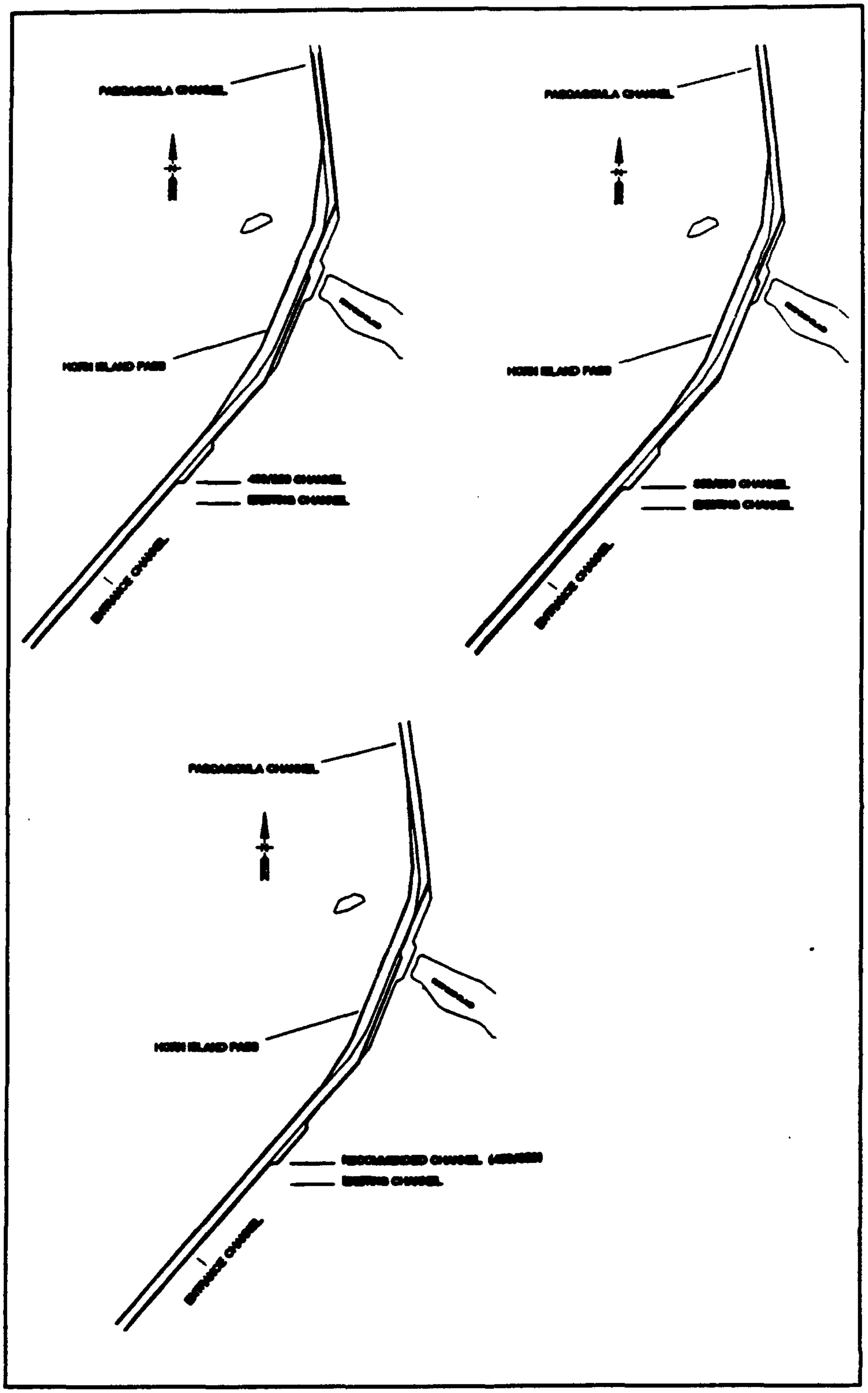

Figure 27. Simulator test channel configurations

Validation Tests

The first Pascagoula pilot to visit WES conducted a brief validation of the simulator model before proceeding with the actual test program. Many of the components of the simulation had already been validated prior to the initial test program; however, some additional pilot opinion was required for such things as the new ship model and the new current condition. The pilot was satisfied that the currents used in the simulation approximated a spring tide situation adequately. The primary modification to the simulation stemming from the validation involved the available rudder angle for the lightering tanker. As mentioned, these ships are equipped with a Schilling type rudder which allows deflection angles up to 70 degrees. This range of rudder movement created a situation in which the pilots tended to lose control of the ship while steering. (It is normal practice for the pilots to take the conn themselves at the WES simulator). It appeared that the pilot, being relatively unfamiliar with the new type of rudder, as well as the simulator, acted as if the ship's wheel on the simulator had a 35-degree maximum angle. When the pilot went hard-over with the rudder, it deflected to 70 degrees instead of the anticipated 35 degrees causing the ship to swing faster and requiring much more time for the rudder to react to a reversal command. Since the pilot stated that rudder commands on an actual ship are not normally issued in excess of 35 degrees in the test area (even with 70 degrees available), it was decided to limit the simulator's wheel to the lower range so the pilots could maintain more realistic operating conditions. It should be noted that Ankudinov 1989 shows that in the deflection angle range of -35 to +35 degrees the effectiveness of the Schilling rudder is not significantly different from a conventional rudder. This suggests that the new lightering tankers will probably not be any easier to control in the Pascagoula entrance than the older vessels.

Trackline Results

Figures 28-31 show composite pilot tracklines for the four test channels of the nighttime simulation testing program. These plots are time-of-day composites depicting the runs of all pilots with both test vessels for daytime and nighttime conditions separately. Each plot includes three tanker runs and two LASH ship runs. The two time-of-day conditions are arranged side-by-side for each test channel for quick comparison. It should be cautioned that the current direction shown on these plots is only for general reference; for a more detailed current pattern depiction see Figure 5.

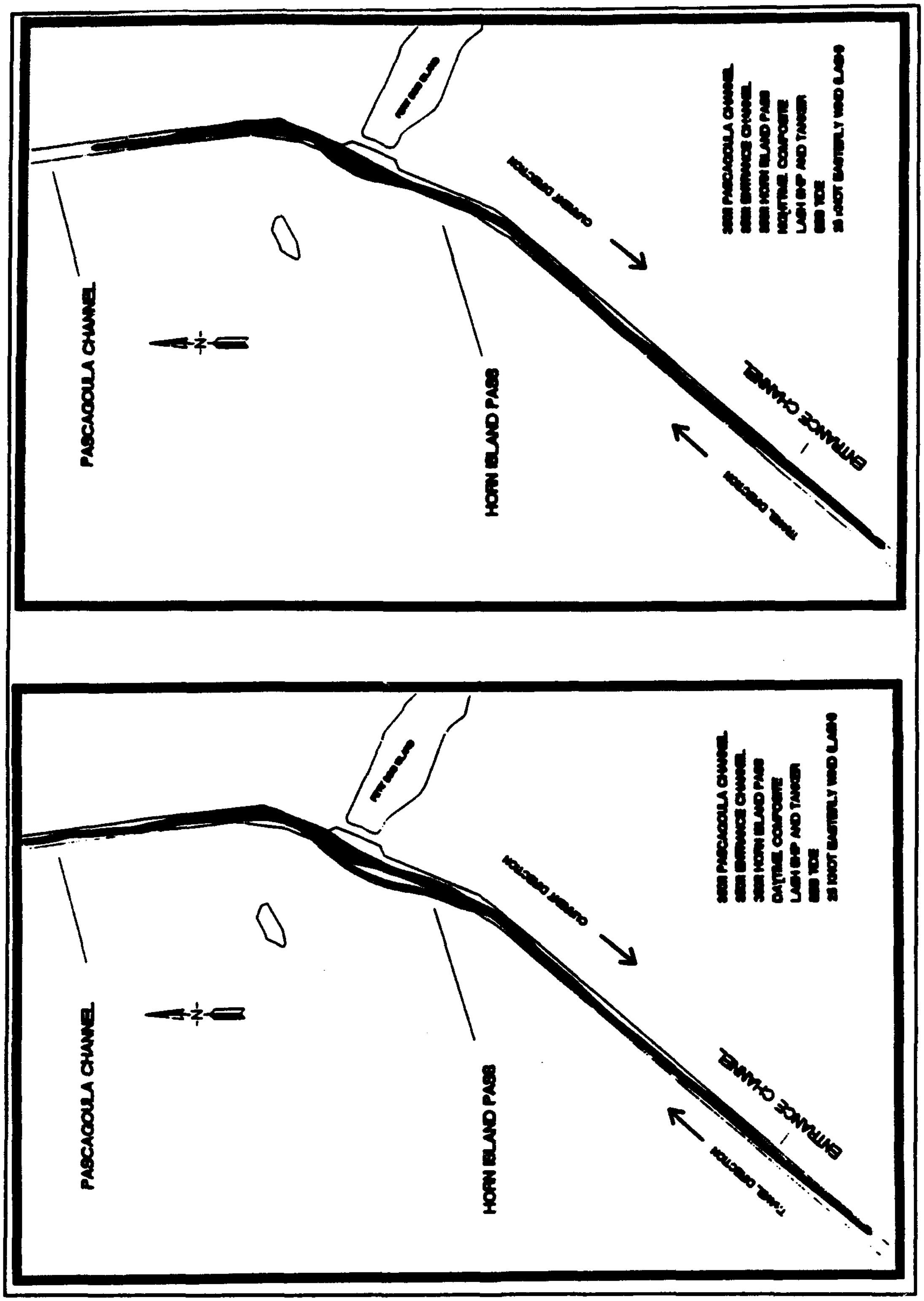

Figure 28. Existing channel composite tracklines for entrance area simulations

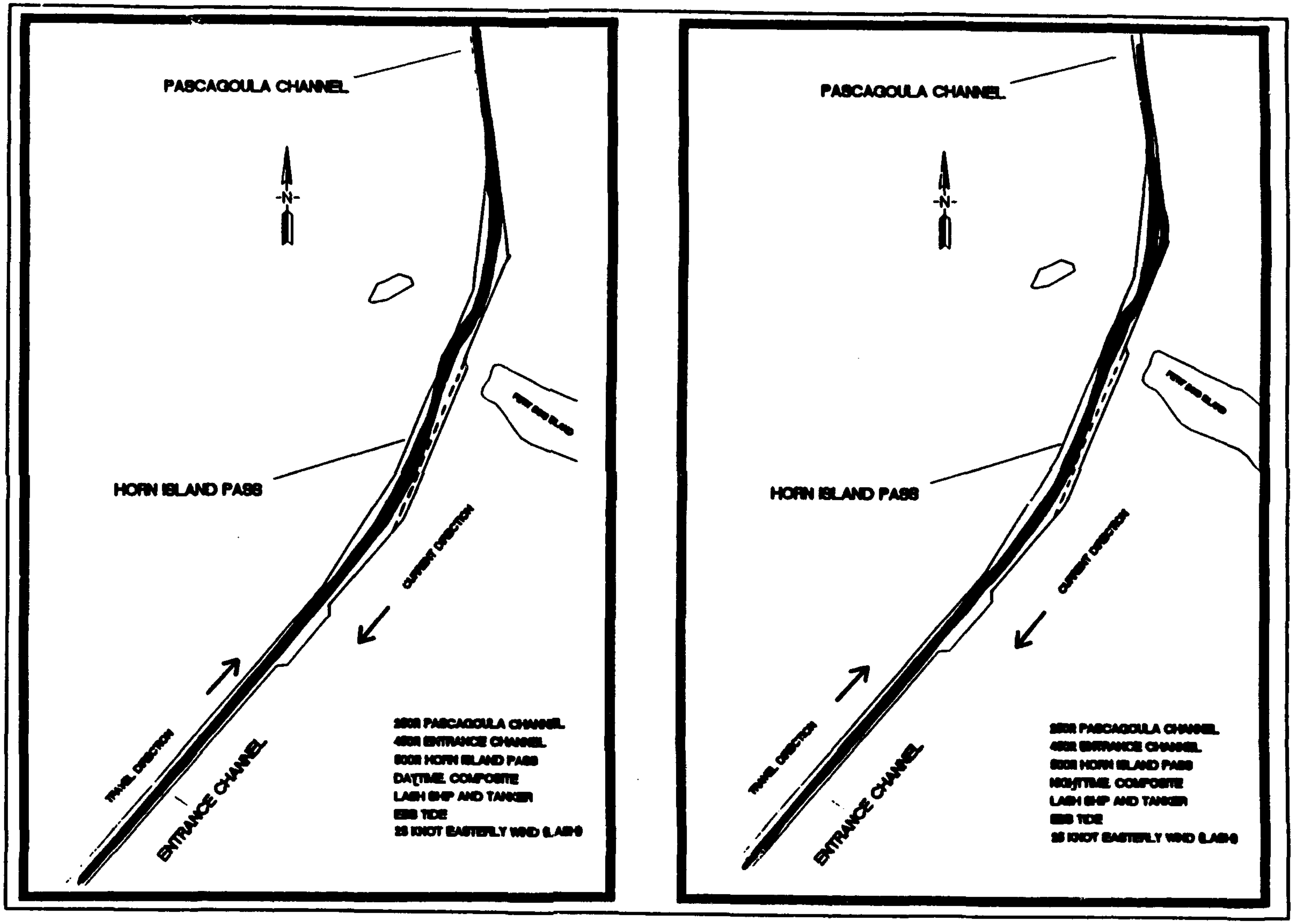

Figure 29. 450/250 channel composite tracklines for entrance area simulations

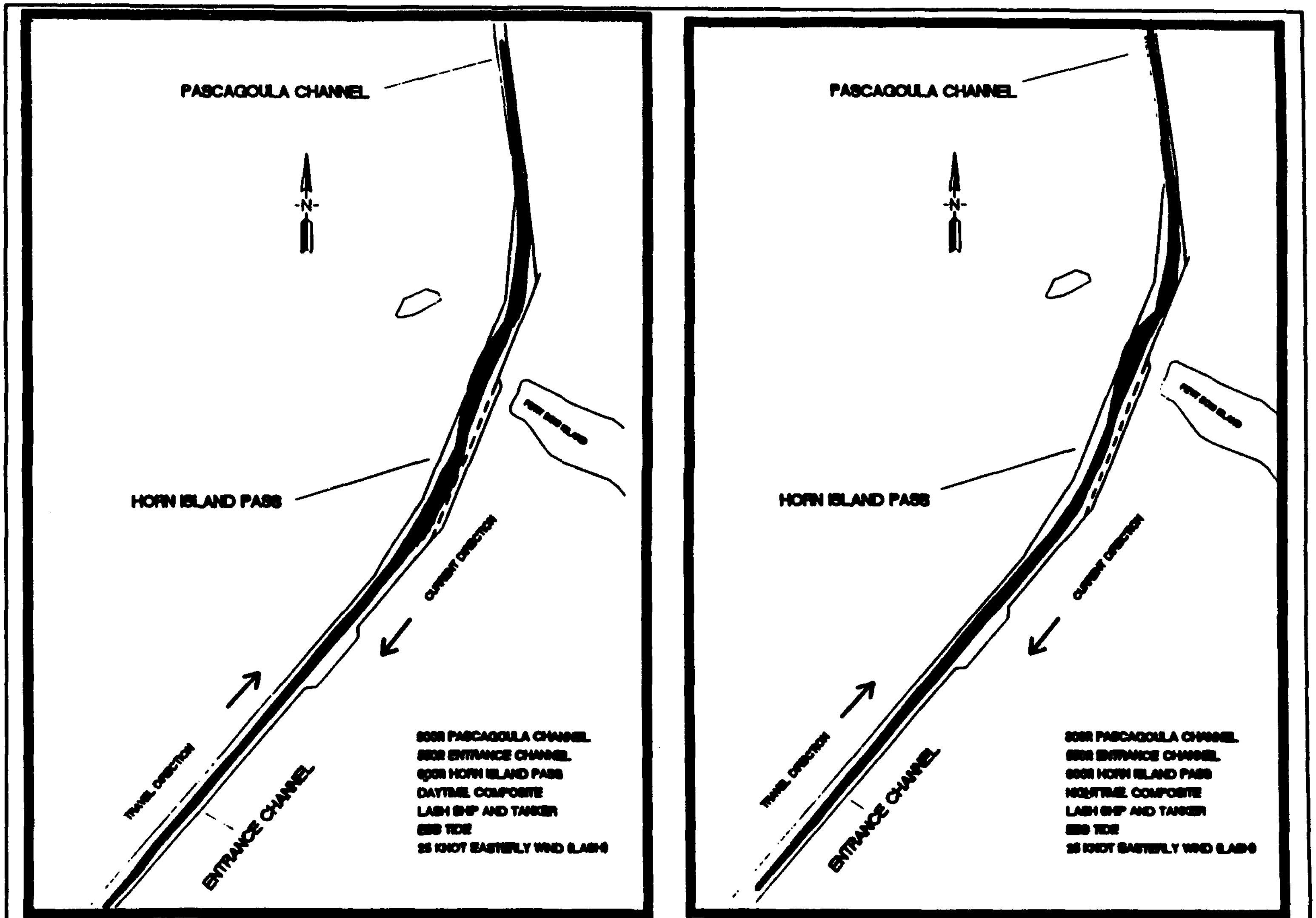

Figure 30. 550/300 channel composite tracklines for entrance area simulations

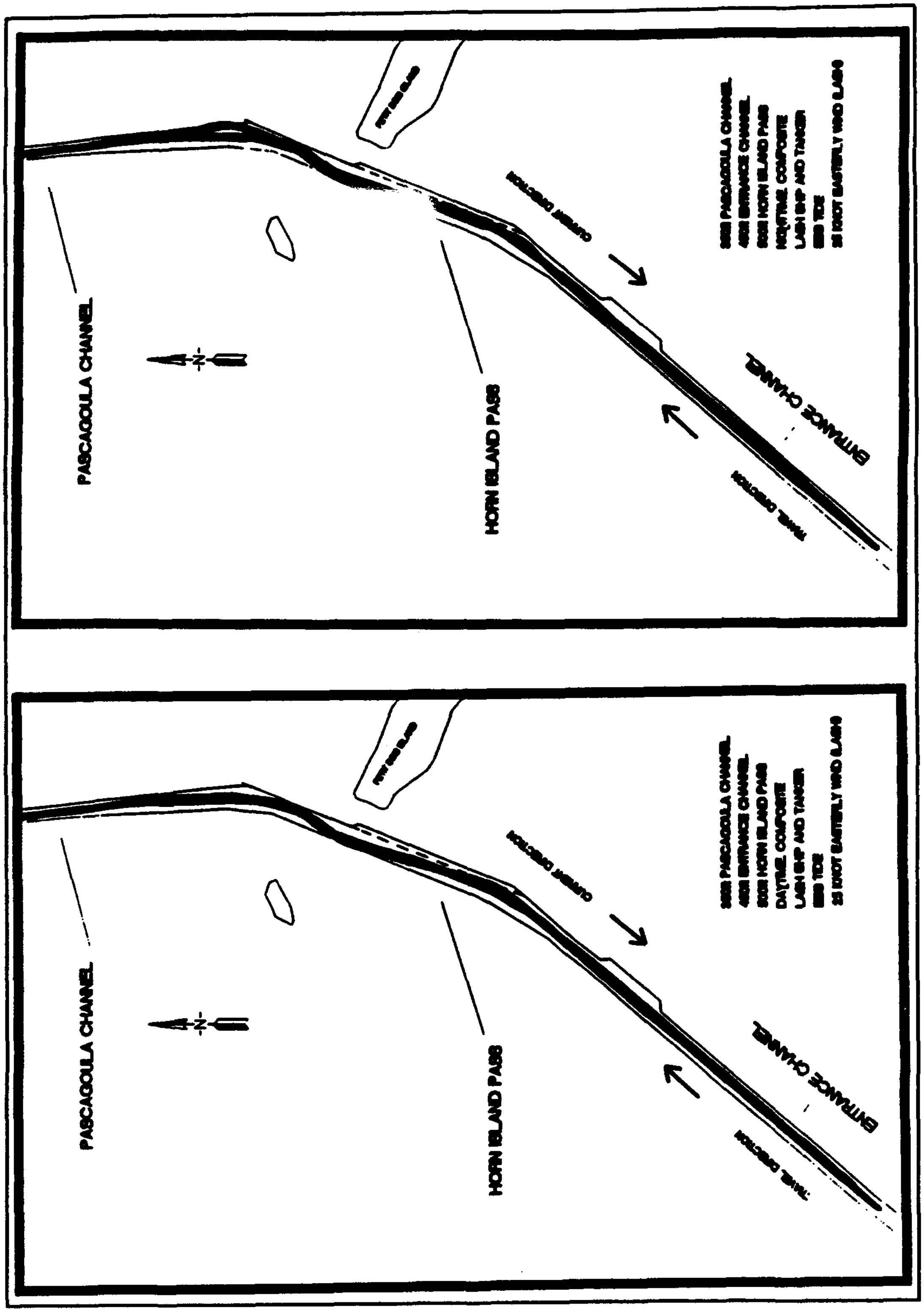

Figure 31. Recommended channel composite tracklines for entrance area simulations

Figure 28 presents the runs for the existing channel. The most obvious pattern seen in these plots is the excursion beyond the western channel limit opposite Petit Bois Island. From pilot comments during these tests, as well as during the earlier simulations, this particular transit path is common, designed to take advantage of naturally deep water on the western side. However, the pilots also generally believed that the bank and current effects in the simulation model were more severe than they expected causing the "S-shaped" path to be more pronounced. This occurrence appears to be more prominent during daytime conditions; however, this apparent day/night difference is considered insignificant because the tracklines from the proposed channel scenarios (to be discussed later) do not show any such difference. Overall, the existing channel tracklines through Horn Island Pass show a very similar pattern to those in the proposed scenarios. Elsewhere, in the Entrance Channel, the daytime runs exhibit a slightly tighter pattern when compared to nighttime runs.

Figure 29 presents the pilot tracklines for the 450/250 proposed channel. The channel reaches are listed on the drawings together with their respective proposed widths. The dashed line on the eastern side of the channel adjacent Petit Bois Island indicates the western edge of the proposed sediment impounding basin marking the authorized channel edge. East of this line the pilots cannot assume the channel will be continuously maintained to the authorized channel depth. Through the Entrance Channel nighttime conditions did not seem to affect the paths of the ships with little trouble evident under either condition. For both daytime and nighttime conditions, the pilots came very close to the edge of the impounding basin during the swing around the first Horn Island Pass bend. After this, the same wide swing around Petit Bois Island as in the existing channel is evident, with insignificant difference due to time of day. Even with the wider channel, drifting beyond the channel limit did occur on the western side. All the pilots performed the typical S-turn around the island and second bend. One pilot during nighttime conditions swung too wide and his trackline extended beyond the channel limit on the eastern side in the bend. After the bend, the pilots had difficulty negotiating the quick transition down to a width of 250 ft, much as they did during the original simulations.

Figure 30 shows the tracklines for the 550/300 channel. Again, little difficulty was experienced in the Entrance Channel; however, a slightly wider trackline spread is evident in the nighttime composite drawing. One pilot came close to the impounding basin edge during daytime conditions following the first bend; other than that, good clearance is seen in the area. Again, for either time of day the pilots conducted the common S-turn around the end of the island and the second bend. However, it is evident that the pilots were able in a few instances to maintain a relatively smooth single turn through the same area (also true in the preceding plots).

Figure 31 shows the tracklines for the channel configuration recommended in the initial simulation program already discussed. This channel is similar to

the 450/250 channel with the exceptions of the Pascagoula Channel being 350 ft wide and the existence of different bend configurations. The S-turn at the end of Petit Bois Island was conducted similarly as in the other channels; however, the composite trackline appears smoother. Little difference is seen in pilot performance between daytime and nighttime runs with the exception of the one pilot who ran out of the channel after the second bend during night conditions. It is evident that when the Horn Island Pass channel was simulated as 500 ft wide (recommended and 450/250 channels) the pilots tended to drift into the sediment basin area on the outside of the first bend. In the 550/300 channel, Figure 30, this occurred with only one pilot. On Figure 31 the gradual transition from the second bend down to the 350-ft width in the Lower Pascagoula Channel seemed to provide the pilots better conditions for the control of their vessels. Comparison of the present tracklines with those on Figures 28, 29, and 30 indicates better control in this area with a smoother path, except for the one trackline mentioned previously.

In an effort to answer a particular pilot concern, a few tests were run using the horizontal wave motion capability on the simulator. This particular modeling capability has not been strictly verified against real data; consequently, it was used in a limited capacity to provide some reasonable measure of the effect of waves on vessel navigation in the Entrance Channel of the Pascagoula Harbor. It was determined that the waves incident from the southeast direction had the longest mean period of 5.7 seconds with a coincident significant wave height of 5 ft. Since this wave direction results in approximately beam waves on a ship in the Entrance Channel, these wave conditions would provide a measure of a reasonably often occurring condition. A period of 5.7 seconds or shorter occurs approximately 80% of the time in the Pascagoula area. In these approximate beam wave conditions it can be expected that wave drift would be close to a maximum which would cause the most difficulty to the pilot in course keeping. Tests were conducted in these wave conditions with the shipmaster in the Entrance Channel and Horn Island Pass for the existing and recommended configurations. One test was run in both of these channels for daytime and nighttime conditions with the loaded tanker. During these runs, the path of the ships did not appreciably change in comparison to the earlier runs without waves. Even with the very low amplitude oscillations noted on the simulator during these runs, the shipmaster stated that the response was too large; therefore, it is reasonable to predict that generally the most frequently occurring wave conditions will not affect navigation in a 450-ft wide Entrance Channel.

Statistical Analysis of Control Measures

Investigation of the entrance area tests involved determining what effect both channel alignment and time of day had on the amount of ship power used. The general premise was that the safest most efficient channel would require a lower level of ship power in comparison to the other alignments.

This investigation centered on statistical analysis of the maneuvering factor, defined during the discussion of the initial simulations. The maneuvering factor was examined in two ways: (a) averaging descriptive statistics for all pilots across each 1000-ft channel section as described earlier, and (b) averaging descriptive statistics for each pilot across the entire channel and then testing for significant differences based on channel design and time of day. The first method was used as before to construct plots showing the variability along the channel of the "average" pilot run. Visual comparisons between different conditions were made. In addition, for the present study this method is taken one step further and the areas under the curves from these plots are graphically determined, then divided by length of channel and used for comparisons between the different test conditions. These results constitute a per-foot-of-channel unit measure of the amount of ship power used. Statistical significance for comparisons cannot be acceptably checked using this method because the averaging procedure reduces the number of samples in each condition and thereby reduces the available degrees of freedom. This problem was remedied by using the second method mentioned above which greatly increases the number of samples per test condition for analysis.

Figures 32-35 show maneuvering factors generated by the first analysis method. These plots are for each of the test channels and include results from both test ships and both night and day runs. As explained above these plots were graphically analyzed for three particular measures: the absolute sum and the algebraic sum of all the areas under the mean curve and the total area under the standard deviation curve. These values were then divided by the length of channel analyzed. Table 4 shows the results of this analysis with the channel design comparison at the top and the time of day comparison at the bottom. Included in the channel comparison are figures resulting from the part of the channel between the second channel bend near Petit Bois Island and where the channel is constricted to the narrow width in the Lower Pascagoula Channel. This latter analysis was carried out to determine if the gradual transition zone in the recommended channel (from the earlier simulations) provided the desired benefit of easier control to the pilots. In the figures for the entire channel, it is interesting to note that all the channels required a net starboard (negative) maneuvering factor despite the fact that the section of the channel tested has two port bends. In other words, the fight against wind (for LASH ships) and ebb current, with the former directed toward the west (equivalent to port for these tests) and the latter also directed toward the west in critical areas, required so much starboard rudder it overwhelmed the requirement to negotiate the two bends. From the table, the figure for the 550/300 channel came closest to being balanced. This is undoubtedly due to the extra channel width available in this case. The variability of the maneuvering factor (standard deviation) was lowest for the recommended channel. The average absolute level of ship power used was actually highest in the recommended channel; however, this is most likely due to a more consistent path taken by the different pilots (compare Figures 28-31) in this particular channel.

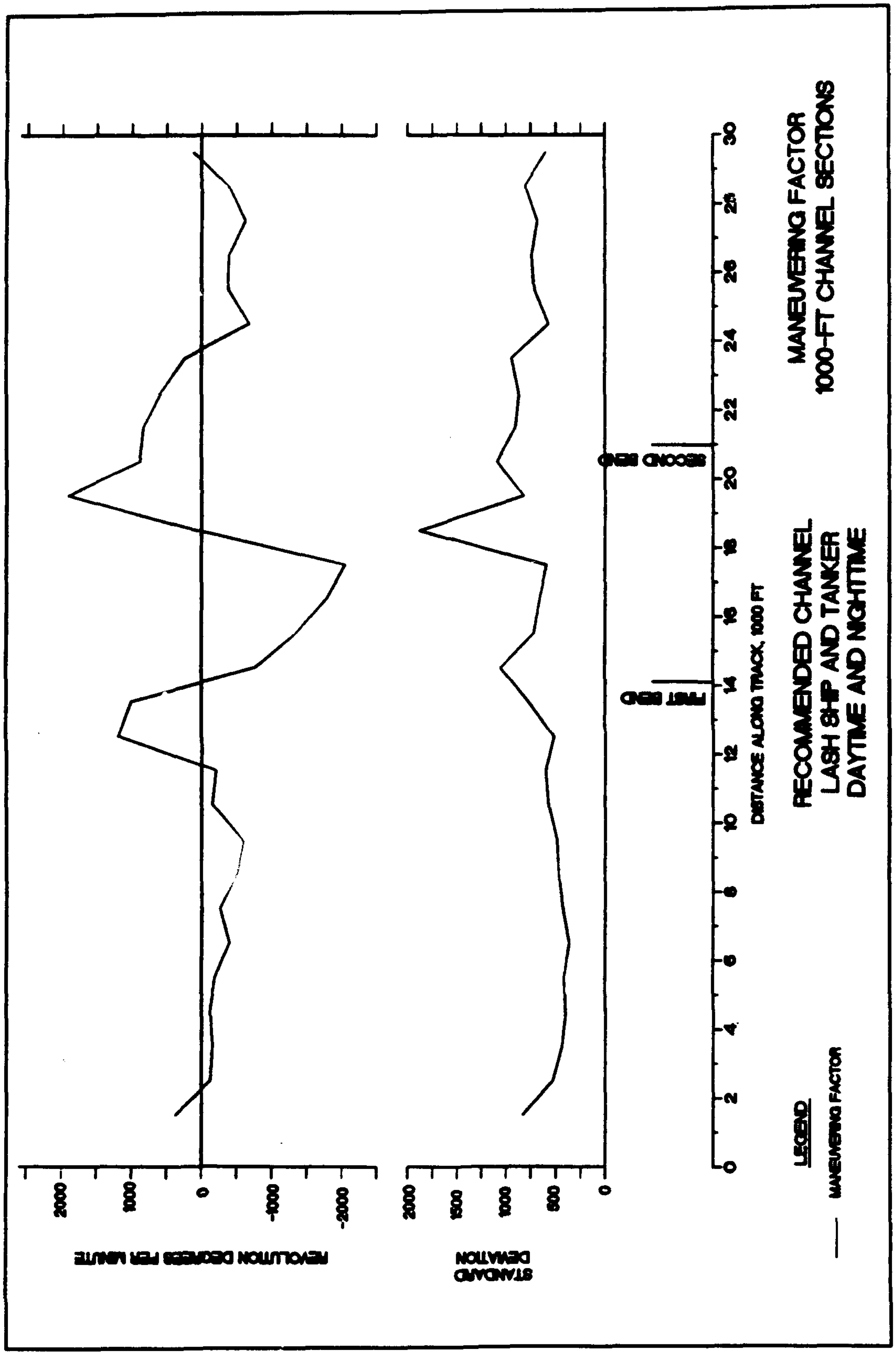

Figure 32. Average maneuvering factor recommended channel

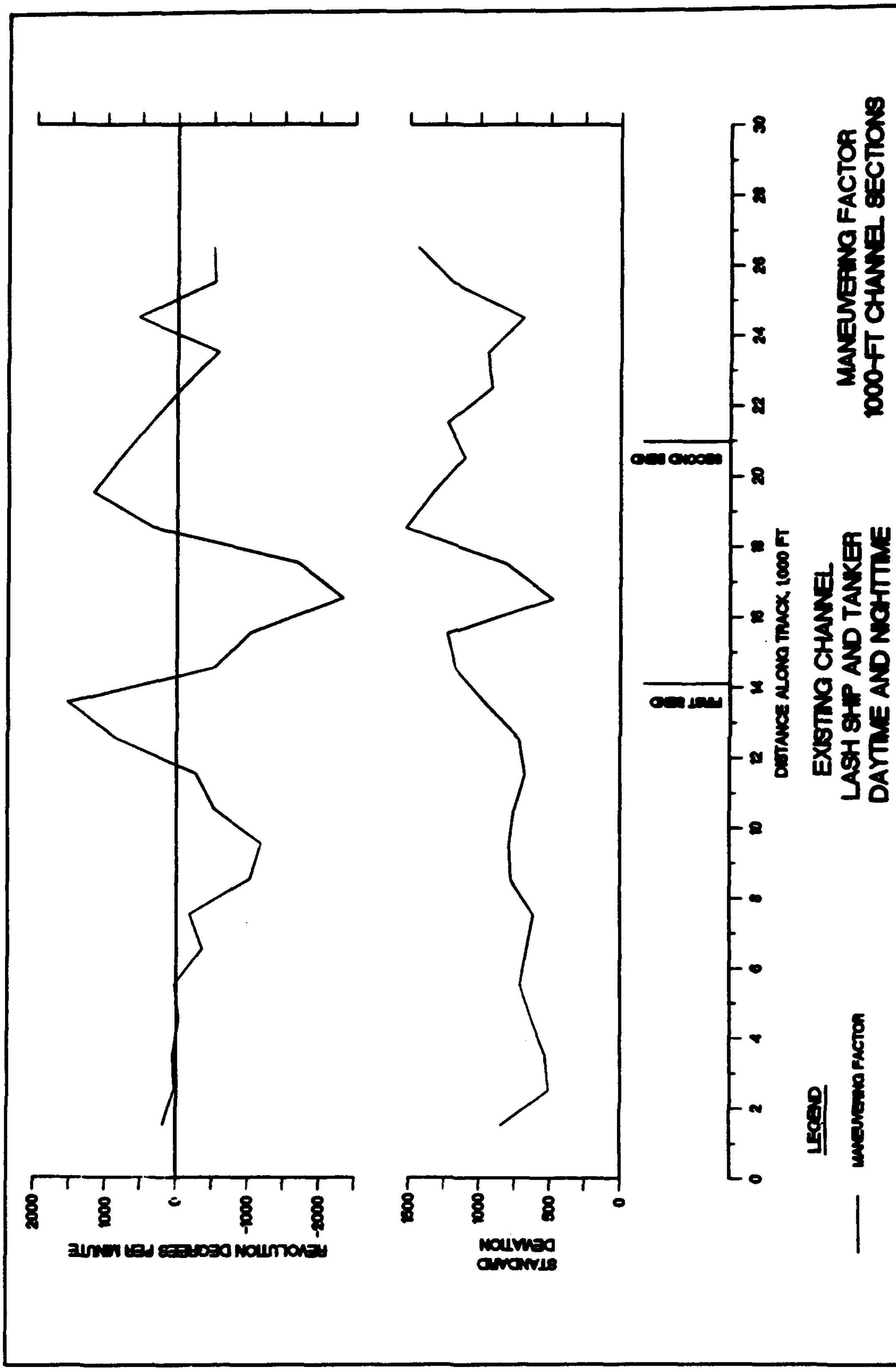

Figure 33. Average maneuvering factor existing channel

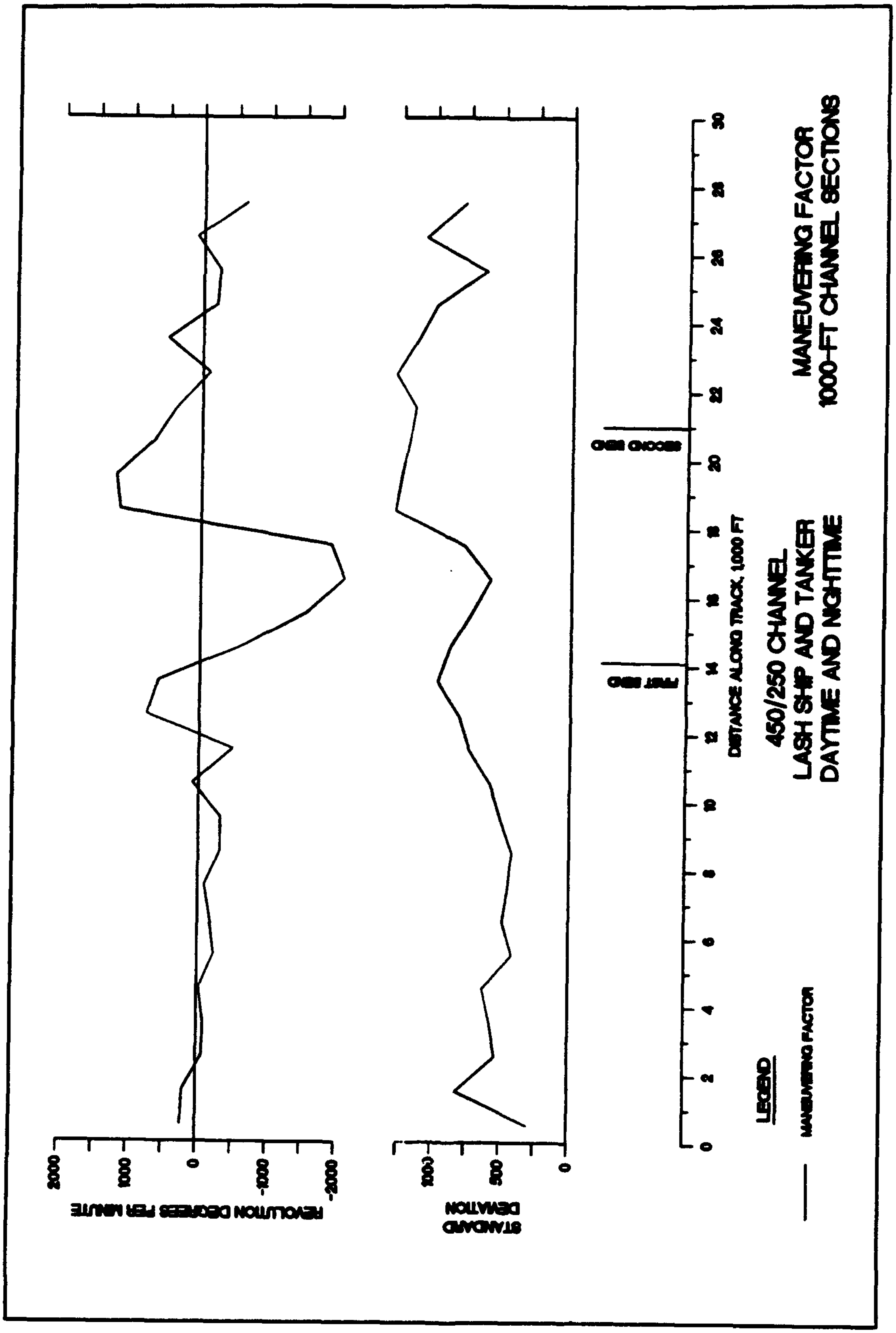

Figure 34. Average maneuvering factor 450/250 channel

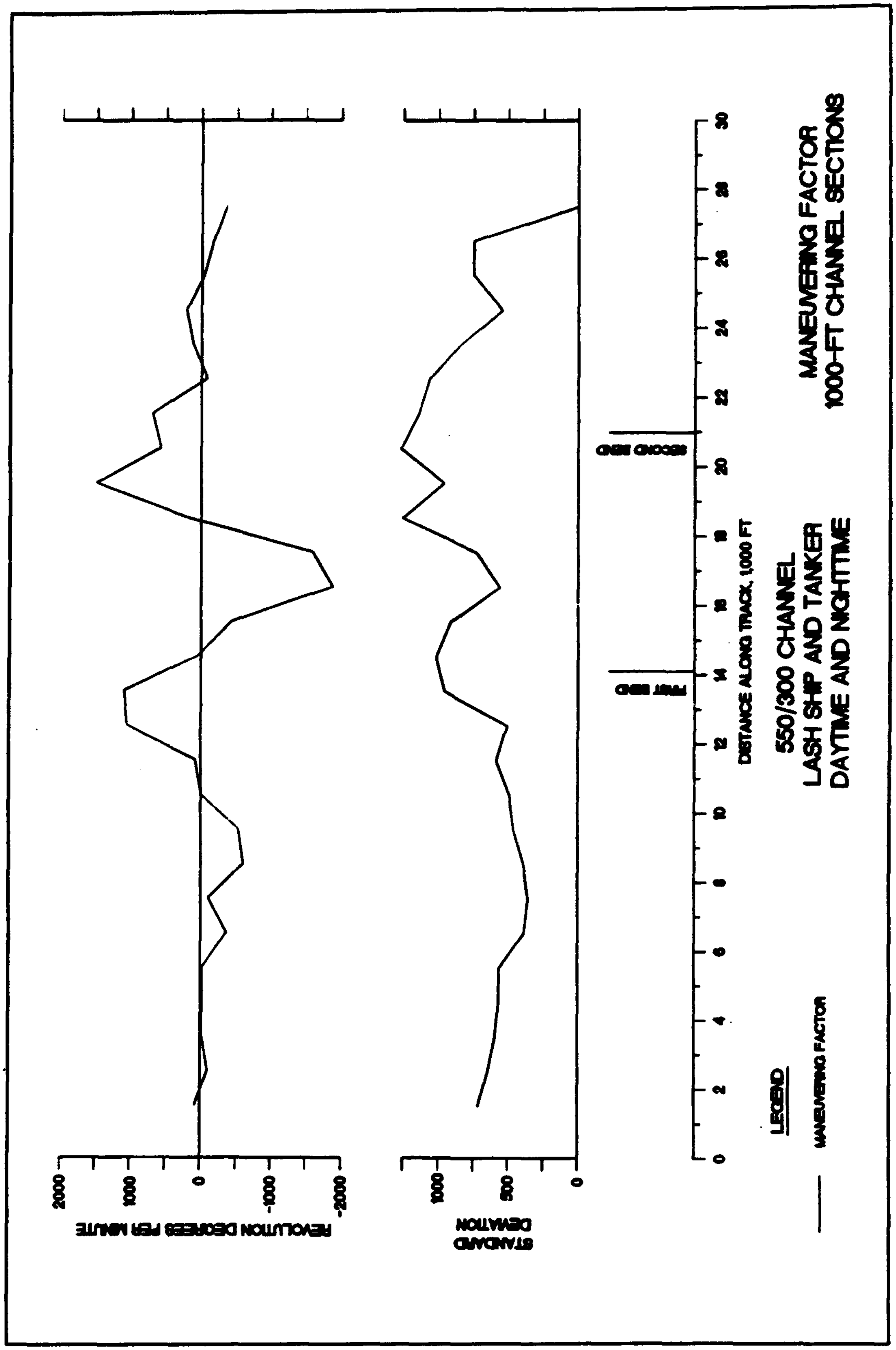

Figure 35. Average maneuvering factor 550/300 channel

Table 4
Average Maneuvering Factor,
(Revolution x Degrees / Minute) per Ft of Channel

Channel Analysis			
Channel	**Absolute**	**Net**	**Standard Deviation**
	Over Entire Run (24,000 Ft)		
Existing	623	-214	919
450/250	505	-126	823
550/300	459	-10	748
Recommended	665	-140	713
	After Second Bend (6,020 Ft)		
Existing	327	-108	1,051
450/250	196	+65	1,048
550/300	194	+118	837
Recommended	252	+18	568

Day versus Night Analysis,
Over Entire Run (24,000 Ft)

Channel	Time of Day	Absolute	Net	Standard Deviation
Existing	Day	620	-152	889
	Night	617	-211	791
450/250	Day	498	-40	799
	Night	551	-232	850
550/300	Day	510	+30	757
	Night	427	-64	726
Recommended	Day	662	-180	688
	Night	686	-209	701

This higher consistency suggests that the pilots were making control decisions at roughly the same points along the channel thereby causing the averages to increase because of a fewer number of offsetting values. In the figures for the channel reach after the second bend, it is evident that the gradual transition in the recommended channel indeed helped the pilots, indicated by the lower variability and more balanced net maneuvering factor in comparison to the other channels. Please note that even in this part of the channel, the port bend, the pilots had to use net starboard ship power in the existing channel. Once again the average absolute power used by the pilots was higher in the recommended channel than in the other proposed channels probably due, again, to a more consistent path taken by the pilots.

Using the second method described earlier, an analysis of variance was carried out on the mean maneuvering factor for the entire run for a test of significance on the differences in the 550/300 channel. The analysis showed that at the 90% confidence level there was indeed a significantly lower level of mean ship power used in the 550/300 channel. From the trackline plots it is evident that the Horn Island Pass required the greatest amount of ship power during the simulation tests. This suggests that the lower levels of maneuvering factor in the 550/300 channel are predominantly attributable to the channel width in this reach. Consequently, the results of this analysis are that 600 ft is needed in the Horn Island Pass leading to a gradual transition down to the recommended 350 ft in the Lower Pascagoula Channel.

Pilot Ratings for Channel Comparison

For the entrance area tests, the same type of pilot questionnaire analysis was carried out as for the initial simulations. The questionnaire handed to the pilots after each run was the same as for the earlier simulations; however, the final debriefing questionnaire was modified for the new tests. Appendix A includes an example of the final questionnaire and the pilots' responses to the questions are listed.

Table 5 shows the normalized average pilot ratings arranged for channel alignment comparisons. Again, negative ratings signify easier conditions for controllability and difficulty and a lower level of accuracy. The pilots on average were rather non-committal concerning the realism of ship behavior except in the 550/300 channel in which a more accurate rating was obtained. The reason for this may be that, based on their comments, the pilots generally considered the bank and current forces to be more severe than expected. Because of wider widths, test conditions in the 550/300 channel were less critical and possibly closer to what the pilots normally experience. For the run difficulty it is evident that the pilots considered the wider channels easier. The lowest rating, for the recommended channel, most likely is a result of the gradual transition allowing the pilot an easier transit.

Table 5 Channel Comparison			
Channel	Difficulty of Run	Accuracy of Ship Behavior	Controllability of Ship
Existing	0.3	-0.1	0.2
450/250	-0.1	-0.1	0.4
550/300	-0.5	0.6	0.0
Recommended	-0.6	0.0	0.2

The ratings for ship controllability are difficult to interpret; however, the widest channel did receive the lowest (easiest) rating.

Daytime versus Nighttime Analysis

Included in Table 4 is a different grouping of maneuvering factor descriptive statistics from the entrance area simulations for a comparison of the amount of ship power the pilots used in daytime and nighttime conditions. These numbers were generated using the first method of statistical analysis described earlier and includes results from all pilot runs. It is evident that the absolute level of ship power and the variability of that power on a per-foot-of-channel basis differs only slightly between daytime and nighttime conditions. For the net maneuvering factor the results show that there is a difference between the two time of day conditions for each of the channels; that is, at nighttime more starboard rudder was used than in daytime. To determine significant statistical difference between night and day runs, the second analysis method was used by generating the net maneuvering factor for each of the pilots' runs separately and performing an analysis of variance based on a day versus night grouping. At a 90% confidence level this procedure indicates that there is no significant difference based on time of day for this particular control measure.

Pilot Ratings for Day versus Night Conditions

Table 6 shows the pilot ratings from Table 5 in a day versus night grouping. In general, the data above indicate that the pilots considered the nighttime runs slightly easier and the ship behavior slightly less accurate than the daytime runs. The actual significance of these results is difficult to determine; however, they do generally reflect the pilots' opinions concerning nighttime simulation runs. Prior to the start of the entrance area tests, the pilots stated that they did not expect any difference on the simulator between daytime and nighttime runs.

Table 6
Day versus Night Comparison

Time of Day	Channel	Difficulty of Run	Controllability of Ship	Accuracy of Ship Behavior
Day	Existing	0.3	-0.1	-0.3
	450/250	0.3	0.6	0.3
	550/300	-0.2	0.8	1.0
	Recommended	-0.6	0.2	0.1
	AVERAGE	-0.1	0.3	0.3
Night	Existing	0.3	0.4	0.1
	450/250	-0.5	0.1	-0.5
	550/300	-0.7	-0.8	0.2
	Recommended	-0.6	0.1	-0.1
	AVERAGE	-0.4	-0.1	-0.2

6 Final Conclusions and Recommendations

Conclusions

The main conclusions of the simulator study are listed below.

a. One of primary control problems which the pilots face in the existing configuration of the Pascagoula harbor area is caused by the interaction between narrow straight channel reaches with high banks and the need of the pilots to slow down in preparation for bends and channel narrowings. Specifically, these difficulties are most predominant at the two entrance area bends and at the entrance to the Bayou Casotte Channel. Adequate channel width and bend widenings are needed to alleviate these problems for the proposed channel conditions.

b. The most critical conditions were not tested in the Upper Pascagoula Channel based on the pilots opinion that the channel was to easy to negotiate. The indication is that the very large bulk carrier used for the proposed conditions was too slow and heavy to react to the bank effects present in the channel. Perhaps a smaller ship with equal draft or a ship with a wider beam would be more critical. It was concluded that since this reach has a similar configuration to the Lower Pascagoula Channel, the conclusions for the latter could be applied here as well.

c. Of the two series of tests conducted in the entrance area, the last simulations presented the most critical set of conditions. Analysis indicates the consistent S-turn that the pilots conduct in the Horn Island Pass is because of a combined effect of the strong spring tidal currents and the bank effects along the eastern side of the channel. As the pilot comes around the first bend and approaches Petit Bois Island, the currents (Figure 5) push the ship toward the east where high banks cause the ship to rotate to port and head to the west. As the ship gets closer to the island, the currents first line up with the channel, and then shift toward the west. The current then acts on the starboard side, reinforcing the western push. After this process starts, the vessel drifts beyond the western channel edge and the pilot reacts with starboard

helm in order to clear the inside corner of the second bend. Furthermore, now, with the ship oriented toward the east, the currents act on the port side of the vessel making it difficult to bring the ship's bow to port to complete the maneuver around the bend. The pilots repeatedly said that this is a realistic sequence of events; however, they also said that the simulated conditions were stronger than they normally experienced. This observation could reflect the fairly infrequent occurrence of inbound transits during a spring tide ebb.

d. In the Bayou Casotte Channel, the channel width is not as critical because of lower currents, slower ship speed and available tug-assist. An exception to this statement is made for the entrance into the channel where additional width is needed for good ship control while slowing down. The simulations showed and the pilots agreed that a constriction in channel width at the pipeline crossing would be acceptable considering the location near the center of the reach far from the entrance. The proposed turning basin is adequate in size, with one modification, and should provide good time reduction benefits to turning vessels.

Recommendations

Despite the pilots' opinions concerning the severity of the simulated conditions, it seems reasonable to recommend increased width in the Horn Island Pass above that which was recommended after the initial simulations. An additional 100 ft on the western side of the channel through the pass would allow more room for the pilots to combat the shifting currents and high banks in the area. In addition, a 100-ft additional widening in the bend between the Entrance Channel and Horn Island Pass would provide the pilots additional room on the western side of the bend to avoid drifting into the proposed sediment impounding basin on the eastern side where available water of project depth cannot be relied upon. Based on these findings, it is recommended that the Horn Island Pass channel be maintained at 600 ft wide. Figure 36 details the recommended dimensions in the entrance area. The recommendations for the navigation channel in the rest of the harbor remain unchanged from the initial simulation tests.

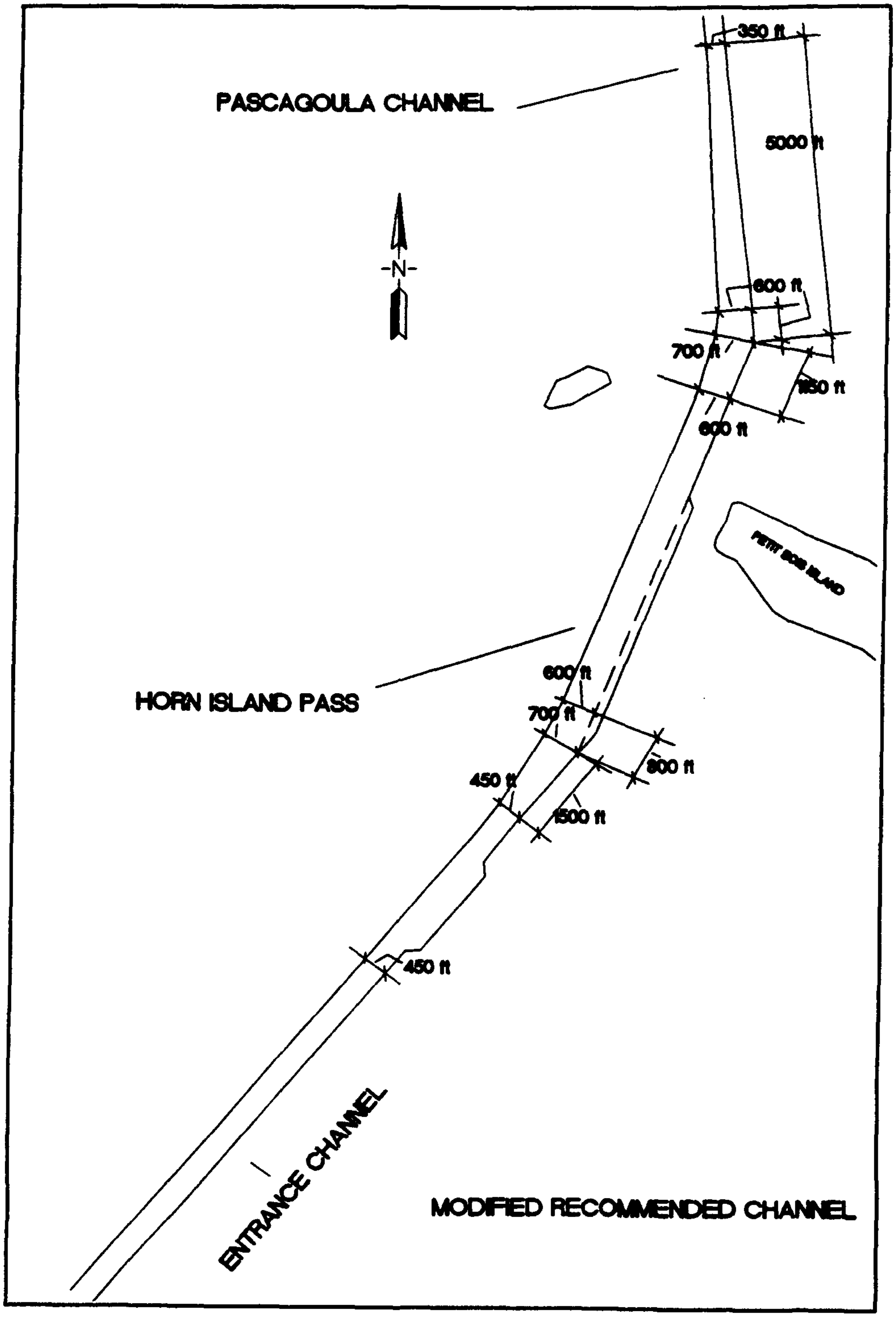

Figure 36. Modified recommended channel based on entrance area simulations

Appendix A
Pilot Comments and Questionnaires

PASCAGOULA PILOT TEST QUESTIONNAIRE
INITIAL SIMULATION TESTS

PILOT ______________________________

RUN CODE ______________________________

RUN START TIME ______________________________

RUN END TIME ______________________________

DATE ______________________________

The purpose of this questionnaire is to document your comments concerning the simulator run you just made. For each question circle your rating on the accompanying scale.

1. How do you rate the difficulty of the last run?

very simple — very difficult

0 1 2 3 4 5 6 7 8 9 10

2. How accurate was the behavior of the ship?

very inaccurate — very accurate

0 1 2 3 4 5 6 7 8 9 10

3. How would you rate the controllability of the ship in the following reaches?

Entrance Channel

very easy — very difficult

0 1 2 3 4 5 6 7 8 9 10

Horn Island Pass

very easy — very difficult

0 1 2 3 4 5 6 7 8 9 10

Lower Pascagoula Channel

very easy — very difficult

0 1 2 3 4 5 6 7 8 9 10

very easy										very difficult	Upper Pascagoula Channel
0	1	2	3	4	5	6	7	8	9	10	

very easy										very difficult	Bayou Casotte Channel
0	1	2	3	4	5	6	7	8	9	10	

4. Overall, how would you rate the accuracy of the simulated bank effects?

very unrealistic										very realistic
0	1	2	3	4	5	6	7	8	9	10

5. Overall, how do you rate the accuracy of the wind effect on the ship?

very unrealistic										very realistic
0	1	2	3	4	5	6	7	8	9	10

6. How accurate were the current effects?

very unrealistic										very realistic
0	1	2	3	4	5	6	7	8	9	10

7. Please feel free to make comments concerning the simulator run you just completed.

PASCAGOULA PILOT TEST QUESTIONNAIRE
ENTRANCE AREA SIMULATION TESTS

PILOT ______________________________

RUN CODE ____________________________

RUN START TIME ______________________

RUN END TIME ________________________

DATE ________________________________

The purpose of this questionnaire is to document your comments concerning the simulator run you just made. For each question circle your rating on the accompanying scale.

1. How do you rate the difficulty of the last run?

very simple — very difficult

0 1 2 3 4 5 6 7 8 9 10

2. How accurate was the behavior of the ship?

very inaccurate — very accurate

0 1 2 3 4 5 6 7 8 9 10

3. How would you rate the controllability of the ship?

very easy — very difficult

0 1 2 3 4 5 6 7 8 9 10

4. Overall, how would you rate the accuracy of the simulated bank effects?

very unrealistic — very realistic

0 1 2 3 4 5 6 7 8 9 10

5. Overall, how do you rate the accuracy of the wind effect on the ship?

very unrealistic										very realistic
0	1	2	3	4	5	6	7	8	9	10

6. How accurate were the current effects?

very unrealistic										very realistic
0	1	2	3	4	5	6	7	8	9	10

7. Please feel free to make comments concerning the simulator run you just completed.

PASCAGOULA HARBOR NAVIGATION STUDY
INITIAL SIMULATION TESTS
FINAL QUESTIONNAIRE

This questionnaire is for the purpose of documenting your thoughts on the proposed changes to the Pascagoula and Bayou Casotte Channels.

1. With the consideration that initial and maintenance dredging costs are major factors in project viability, what channel widths would you recommend in the following reaches? Please explain, with specifics, the reasons for your answers.

   a. Entrance Channel (from buoy #5 and #6, seaward)

   b. Horn Island Pass

   c. Lower Pascagoula Channel

   d. Upper Pascagoula Channel

   e. Bayou Casotte Channel

2. Given a specific channel width, what do you recommend as the minimum desirable narrowing at the specific pipeline crossings in the area, e.g., should the constriction be only 50 ft narrower than the channel or is a value of 100 ft acceptable? Please explain.

3. Were the bend widenings in the proposed channels adequate? Please specify points of concern, if any.

4. List any recommended modifications that you feel are necessary to the system of navigation aids in the channels.

5. Was the turning basin design in the Bayou Casotte channel adequate?

6. In your opinion what are some of the improvements needed in the simulation which might enhance our ability to conduct navigation studies.

PILOT RESPONSES TO FINAL QUESTIONNAIRE
INITIAL SIMULATION TESTS

QUESTION 1

a. Entrance Channel

Pilot A - 400 to 600 ft due to strong sets encountered as a result of wind & current. As related to the large deep draft ships we are expected to handle.

Pilot B - No less than 500 ft. The new Chevron "R. Hal Dean" class of crude tankers utilizing the channel are extremely sluggish and need a larger channel. The "Sam Houston" class of LASH ships are oversized for the present channel.

Pilot C - 550 ft minimum width because of the tremendous cross current and also strong cross winds for our length of ships.

Pilot D - 550 ft because of swells, current and the large vessels that come into the Pass. And wanting to bring large vessels in at night.

Pilot E - 600 ft, present width inadequate for night piloting, and current effect.

b. Horn Island Pass

Pilot A - 400 ft - strong sets are encountered up to buoy 15.

Pilot B - Same as Entrance Channel.

Pilot C - From buoy 15 to buoy 11 same as is today, from buoy 11 to buoy 5 600 feet because of cross currents.

Pilot D - Same as Entrance Channel.

Pilot E - 600 ft, present width inadequate for night piloting and current effect.

c. Lower Pascagoula Channel

Pilot A - 350 - 400 ft. At faster speeds sometimes required to transit the bar channel it would help to have a wider channel in this area for slowing down.

Pilot B - Deepen to 42 ft. Ship squat creates maneuvering difficulties and a 38 ft channel silts quickly restricting 36 ft drafts.

Pilot C - We recommend 350 ft as is. This is a fine width for our ships we now handle.

Pilot D - At least 350 ft.

Pilot E - 400 ft, presently no room for margin of error or operation in poor visibility or restricted visibility.

d. Upper Pascagoula Channel

Pilot A - 350 ft.

Pilot B - Same as Lower Pascagoula Channel

Pilot C - We recommend 350 ft as is today, fine for the ships we now handle.

Pilot D - At least 350 ft.

Pilot E - Same as Lower Pascagoula Channel.

e. Bayou Casotte Channel

Pilot A - 350 ft

Pilot B - Widen to 275 ft and deepen to 40 ft. The width presently causes the existing traffic (785'x123'x36') difficulty in passage.

Pilot C - 350 ft recommended for Bayou Casotte, the shoaling in the channel might be reduced as is the Casotte Channel is not free of shoaling but about 5 months a year.

Pilot D - Maybe 300 ft.

Pilot E - Same as Lower Pascagoula Channel.

QUESTION 2

Pilot A - I recommend only 50 ft narrower in order to minimize bank effects since the pipeline crossings in some cases are close to the turn at buoy 30 [near channel intersection].

Pilot B - I recommend only 50 ft narrower unless the length of constriction is short, say, no more than 1200 ft overall; that is 2 ship lengths.

Pilot C - If the idea is to narrow the existing channel I don't believe the channel should be any narrower at any point so the specific pipeline crossing now is acceptable. I can't feel that the narrowing of any part of our channel will be anything but a disaster with the conditions we have which the computer cannot justify.

Pilot D - It should be no more than 50 ft, if possible no constriction at all. Because of currents and winds

and sometimes reduced visibility. Another reason is where the pipelines are located is where we are slowing the ships down, so the effects of the wind and currents are a lot greater on the ship.

Pilot E - 100 ft would be acceptable if well marked.

QUESTION 3

Pilot A - The widening appears to be adequate based on my experience on the simulator.

Pilot B - They were adequate for normal traffic. For ships in excess of 900 ft they may not be sufficient.

Pilot C - Yes, the bend widenings are a great help. Also, a bad bottle neck is from beacon #10 Bayou Casotte to Chevron #7 berth - just shave that corner off.

Pilot D - I found the bend widenings very adequate.

Pilot E - Yes, except the LASH ship simulation inbound at buoy #13 gave me extreme difficulty, need a longer easement.

QUESTION 4

Pilot A - Add a light to buoy 30 [at channel intersection]. Raise the height of range C for Pascagoula Channel. Put a Raycon on the sea buoy.

Pilot B - None

Pilot C - Our navigation aids are up to par.

Pilot D - No recommendation.

Pilot E - Aids are adequate.

QUESTION 5

Pilot A - [Was not asked this question]

Pilot B - [Was not asked this question]

Pilot C - Yes I believe it would be great if we could just get it.

Pilot D - Yes, with maybe a couple of alterations.

Pilot E - No, a square basin would be more acceptable.

PASCAGOULA HARBOR NAVIGATION STUDY
ENTRANCE AREA SIMULATIONS
FINAL QUESTIONNAIRE

This questionnaire is for the purpose of documenting your thoughts on the different channel configurations tested during day and night time transits in the Pascagoula Entrance Channel and Horn Island Pass.

1. What differences did you experience between day and night transits on the simulator?

2. In your opinion, which of the ships tested (tanker or LASH) was more critical?

3. Which of the channel configurations tested in the simulation would be adequate for the Entrance Channel and Horn Island Pass?

4. Can you think of any possible modifications for the simulator which might enhance our ability to conduct navigation studies?

PILOT RESPONSES TO FINAL QUESTIONNAIRE
ENTRANCE AREA SIMULATION TESTS

QUESTION 1

Pilot A - Minor differences, slightly more difficult on the night shift except 40 ft draft ships [quite] a bit harder at night.

Pilot B - Not much difference, other than having a black background. But it was a little more difficult.

Pilot C - Day simpler probably because of the apparent increase in vision depth, etc.

QUESTION 2

Pilot A - The LASH ship was more critical.

Pilot B - After several transits, they both acted the same.

Pilot C - Only tested tanker.

QUESTION 3

Pilot A - For the two ships studied the 550 ft channel is great but the 450 channel with wdening off the island proved adequate with no more than 36 ft draft.

Pilot B - The bend widenings seem to be adequate. Except having trouble around the Island. But the bar channel (buoys 1 and 2 to 7-8-9) cannot be adequately simulated because of the swell that we have across the channel 50 percent of the year.

Pilot C - The 450/500/350 [recommended] would appear to be satisfactory - certainly the last leg should not be less than 350 ft.

QUESTION 4

Pilot A - I believe the system you have would be hard to beat. You are using the largest regular ships we have and maximum drafts.

Pilot B - Have the ability to simulate the forces that swell or heavy seas [affect] the navigation of ships.

Pilot C - Helm and rudder indicator could be more readable - made larger and angled better.

QUESTION 6

Pilot A - Add the [existing] Pascagoula River and Bayou Casotte Turning Basins.

Pilot B - I can think of none.

Pilot C - The bank effects the current and wind effects that I know of some way to get the speed entering the harbor down to a minimum perhaps this is up to the pilot with a little practice on the computer. In this test I feel that I was going too fast several times normally in real life we use tugs to slow us down.

Pilot D - It was hard to tell the difference between the ships simulated. Because of using the same controller for all the ships. The only way to me was one ship looked on the screen different and one was faster.

Pilot E - The rudder angle indicator moves to freely causing excessive use of rudder. Tilt indicators toward the pilot so he can view them easier without having to lean forward.

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13. ABSTRACT (Maximum 200 words)

A real-time ship simulation study of the proposed design for deepening and widening the man-made Pascagoula channels, Pascagoula, MS, was conducted. The purpose of the study was to determine the required channel width and alignment to deepen the channel from 40 ft to 44 ft in the entrance channel and from 38 ft to 42 ft in the inside channels. Numerical current models for the existing and proposed channels were developed, and the currents were verified in the simulator by members of the Pascagoula Bar Pilots Association. Tests were conducted in Vicksburg, MS, on the U.S. Army Engineer Waterways Experiment Station ship simulator.

These tests determined the optimum width and alignment for the Pascagoula channels.

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